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*Primary Examiner* — Melanie Torres Williams

(74) *Attorney, Agent, or Firm* — Oliff & Berridge, PLC

(57) **ABSTRACT**

A vibration damping device including: a rubber elastic body connecting first and second mounting members; a partition member supported on the second mounting member; a pressure-receiving chamber and an equilibrium chamber connected by a first orifice passage; an oscillating plate defining the pressure-receiving chamber; and an electromagnetic actuator for actuating the oscillating plate. The oscillating plate is constituted by a cylinder shaped hole and a piston shaped plate accommodated within the cylinder shaped hole with a gap provided therebetween. An output member of the electromagnetic actuator is linked to the piston shaped plate. A plate spring extending in an axis-perpendicular direction is disposed to an opposite side from the electromagnetic actuator with the piston shaped plate therebetween, with the oscillating plate linked to and supported in an axial direction with respect to the partition member by the plate spring.

**9 Claims, 6 Drawing Sheets**

(52) U.S. Cl. .... 267/140.14

(58) **Field of Classification**  
**Search** ..... 267/140.13–140.15, 219, 141,  
267/141.1–141.4; 248/562, 636, 638  
See application file for complete search history.

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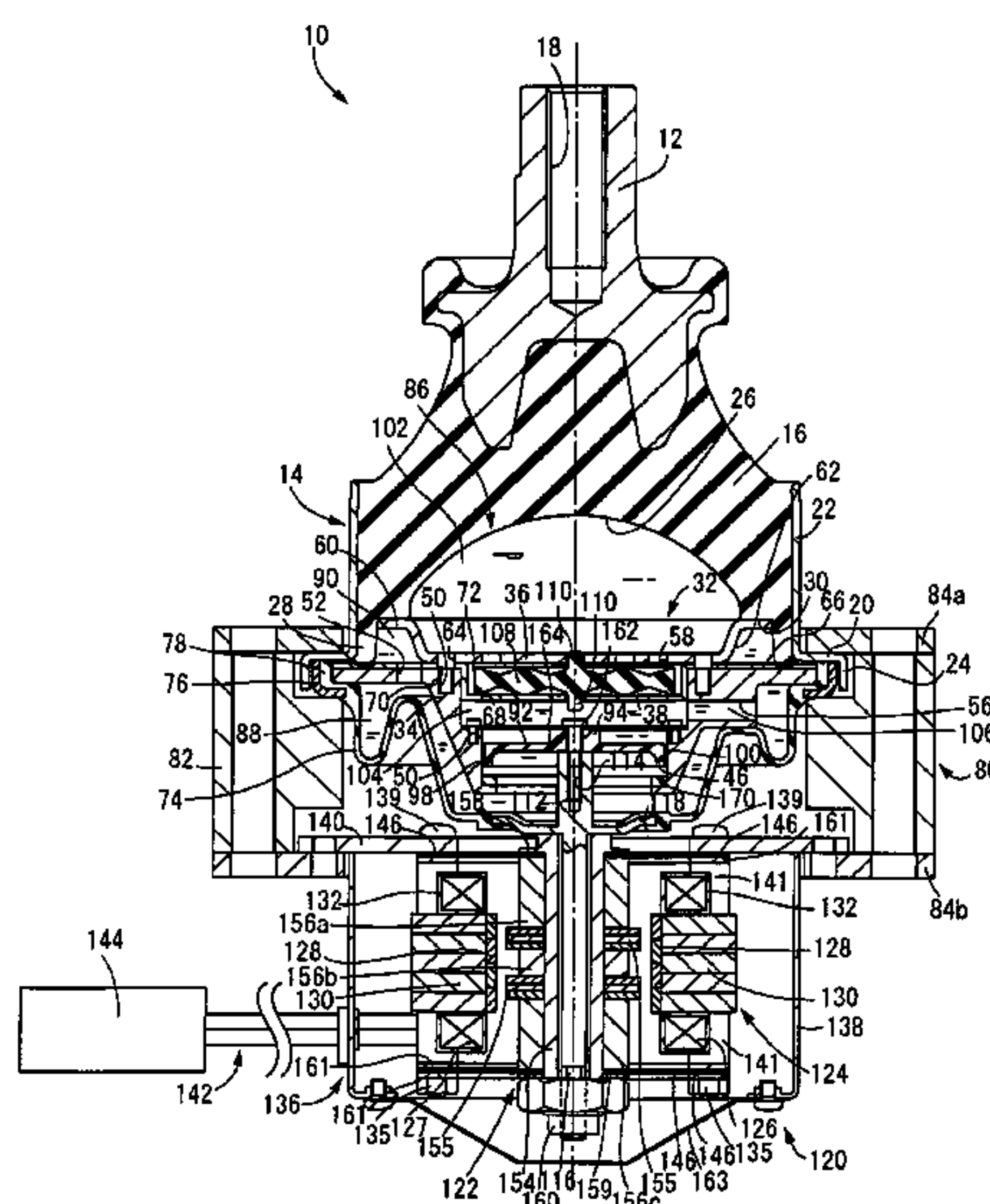
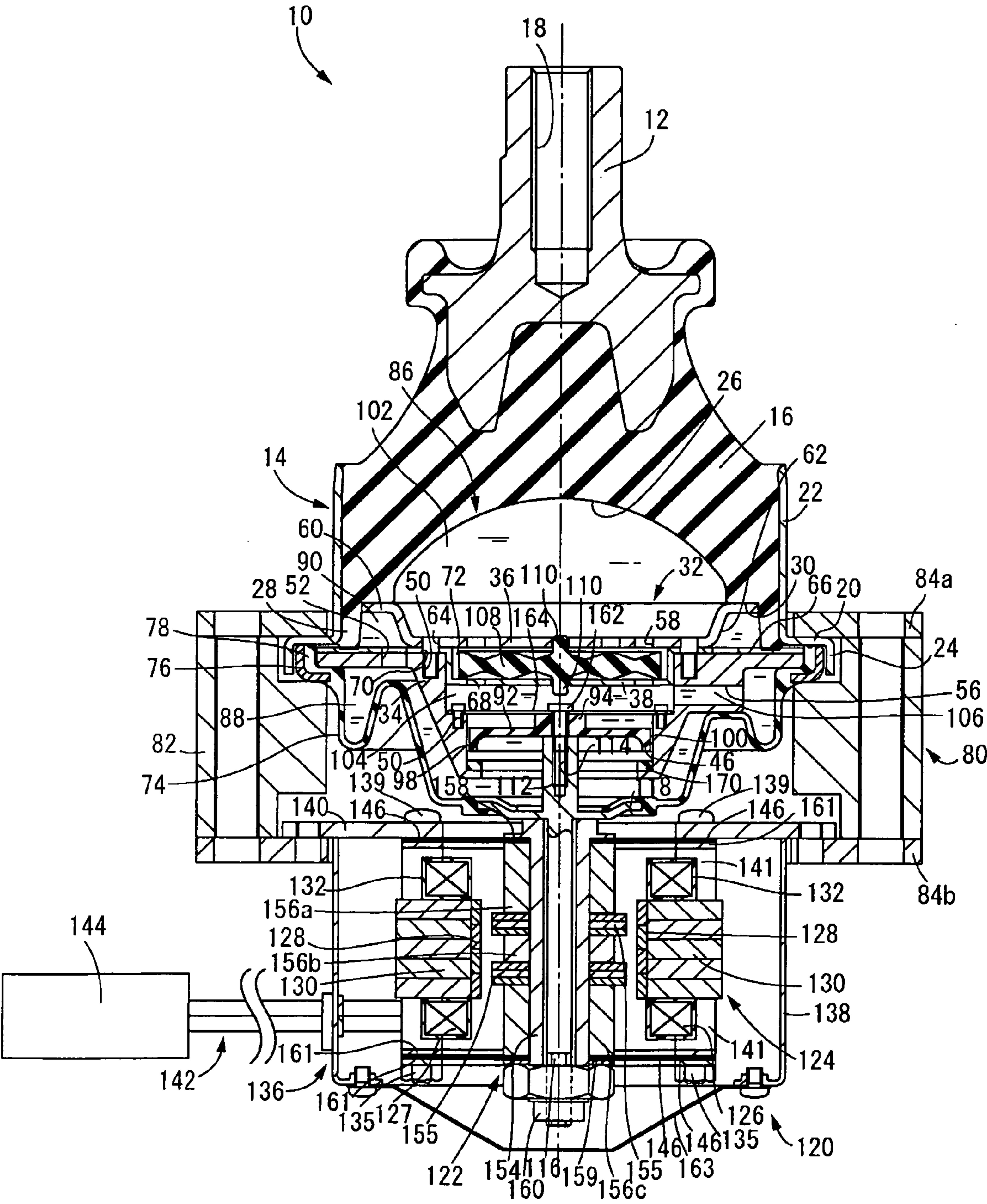


FIG. 1



**FIG.2**

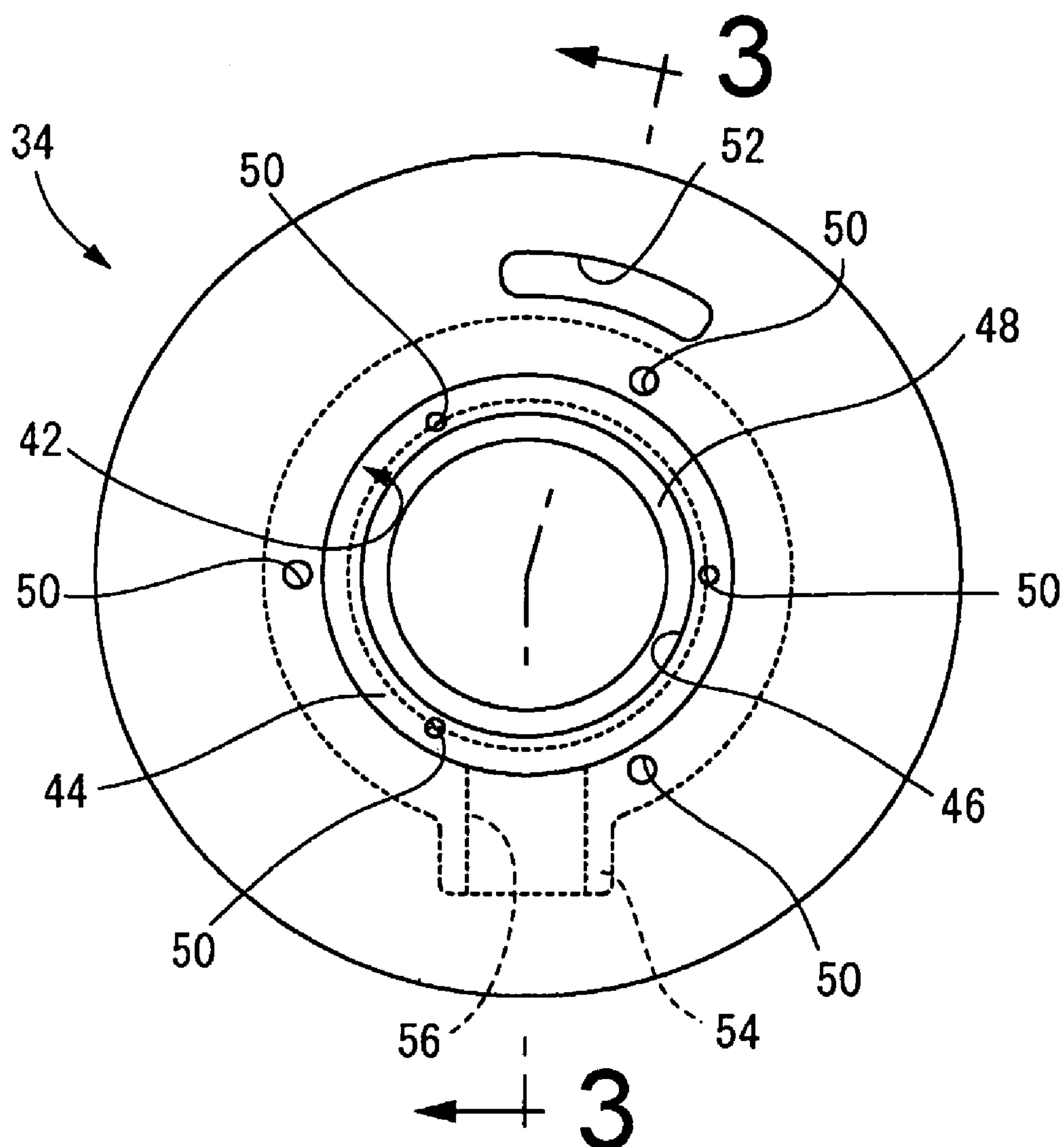


FIG.3

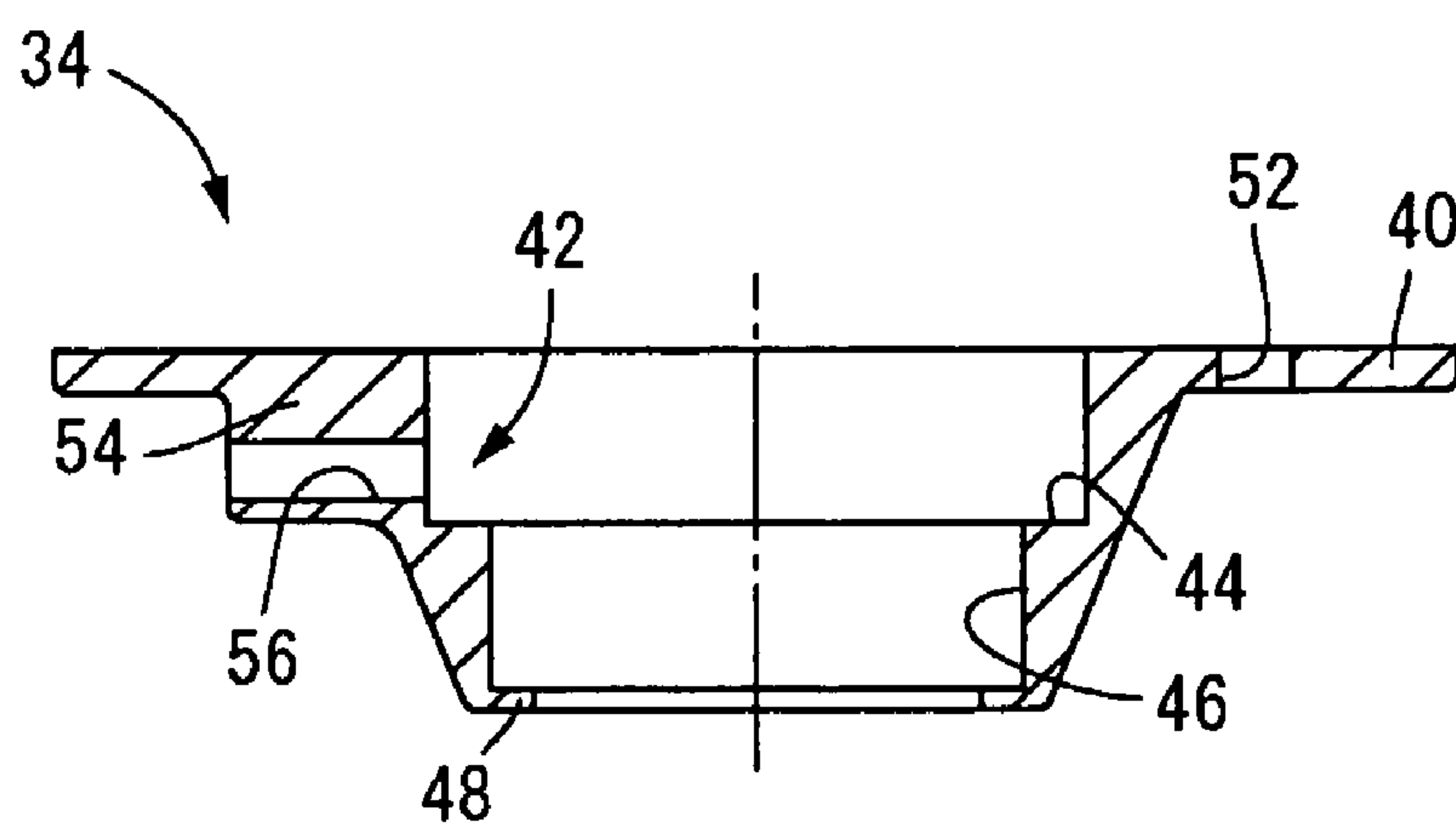
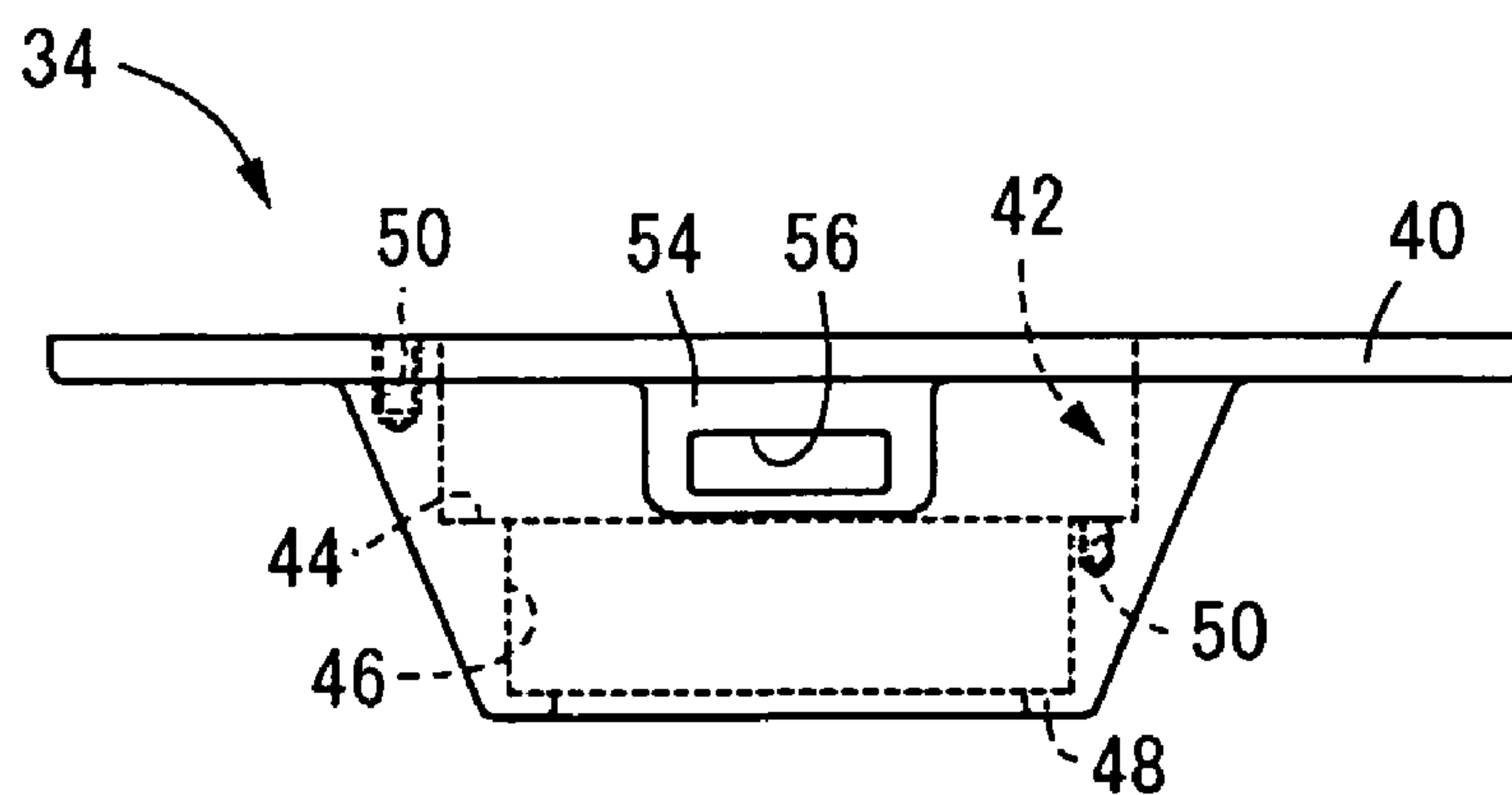
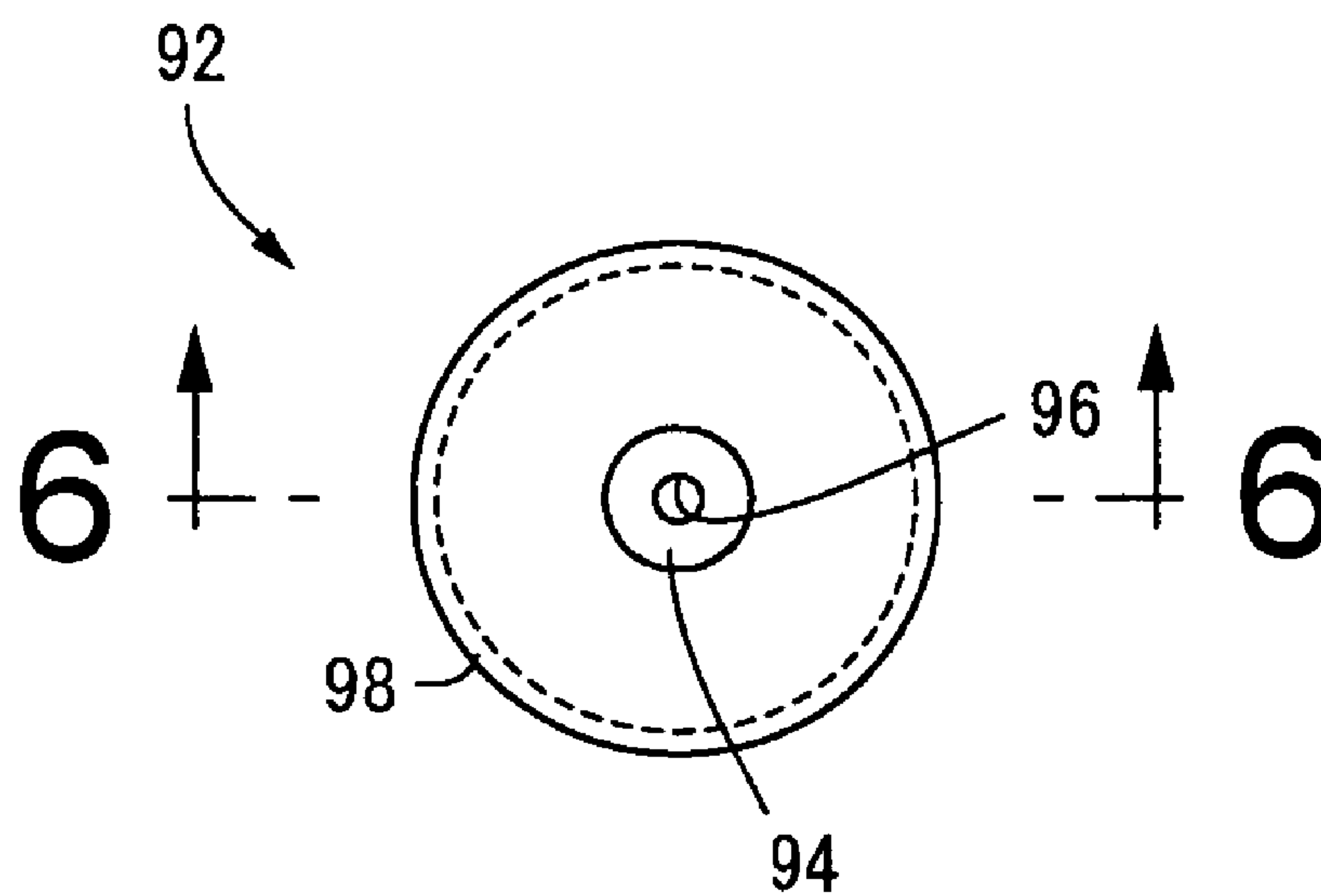


FIG.4



# FIG. 5



# FIG. 6

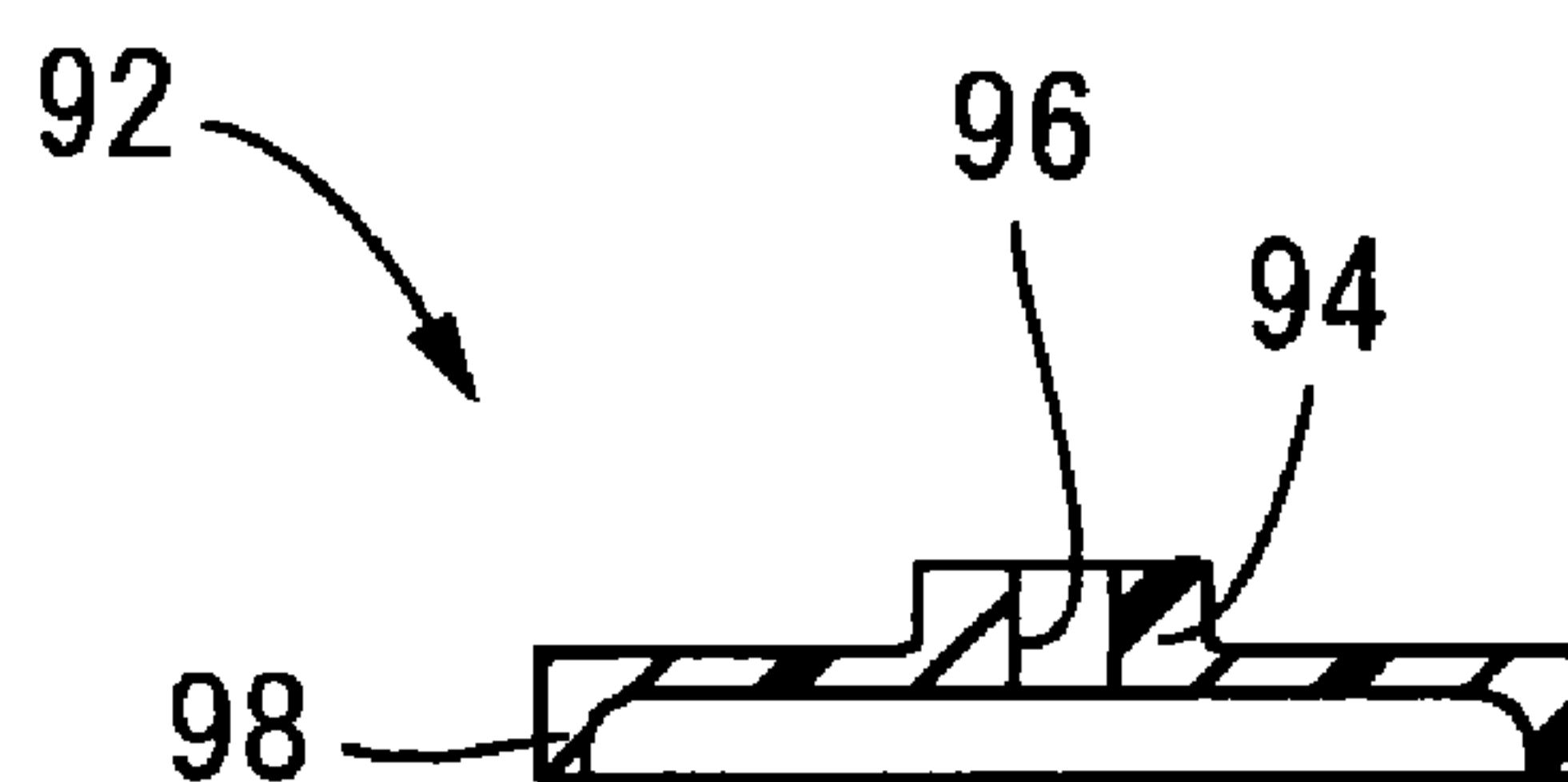




FIG. 7

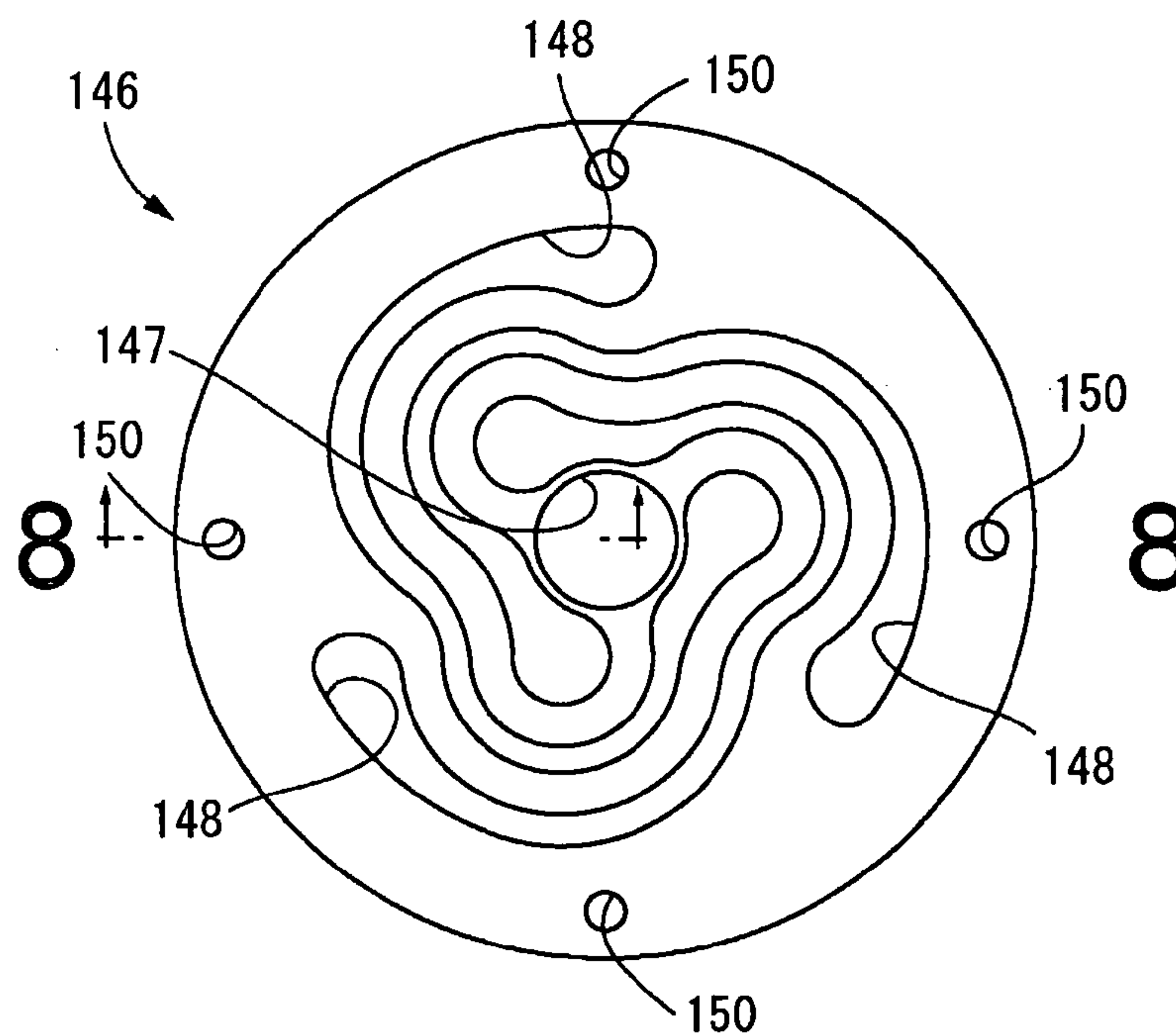


FIG. 8

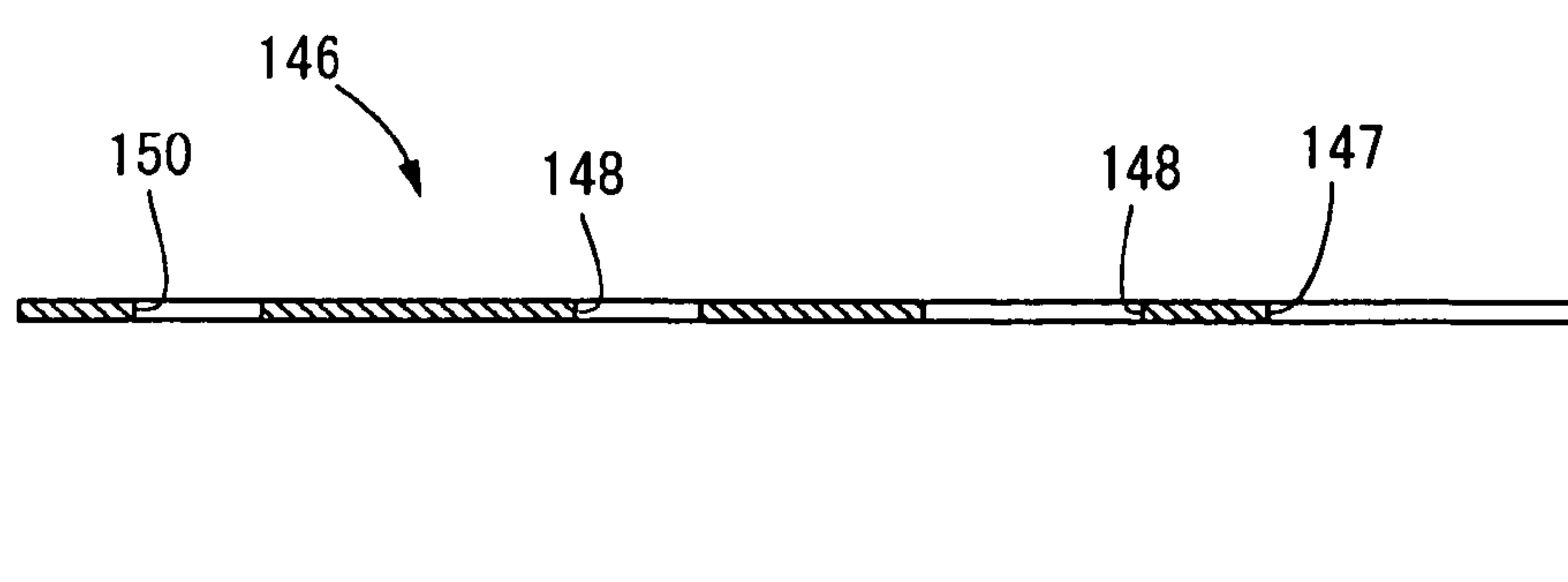


FIG. 9

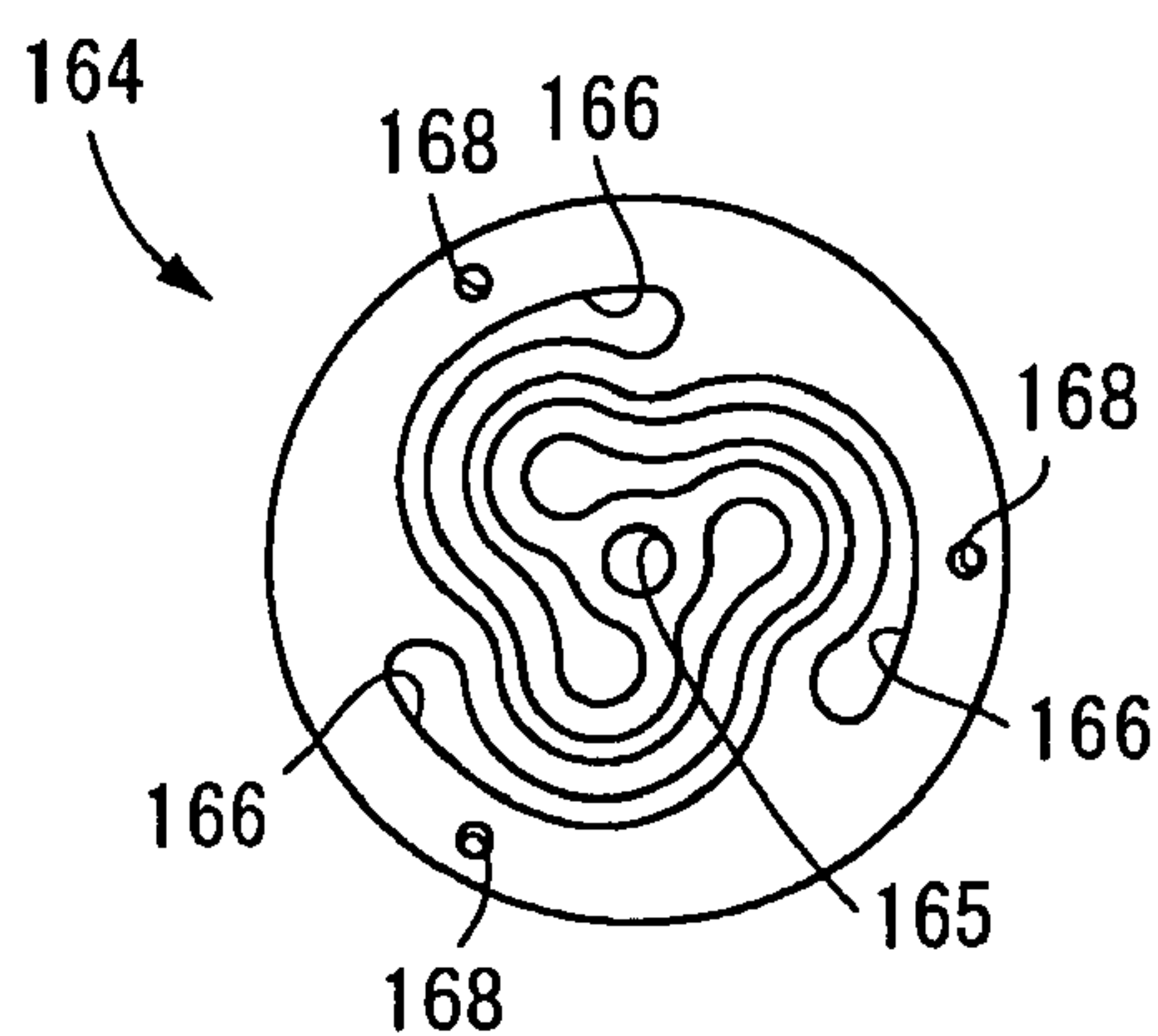
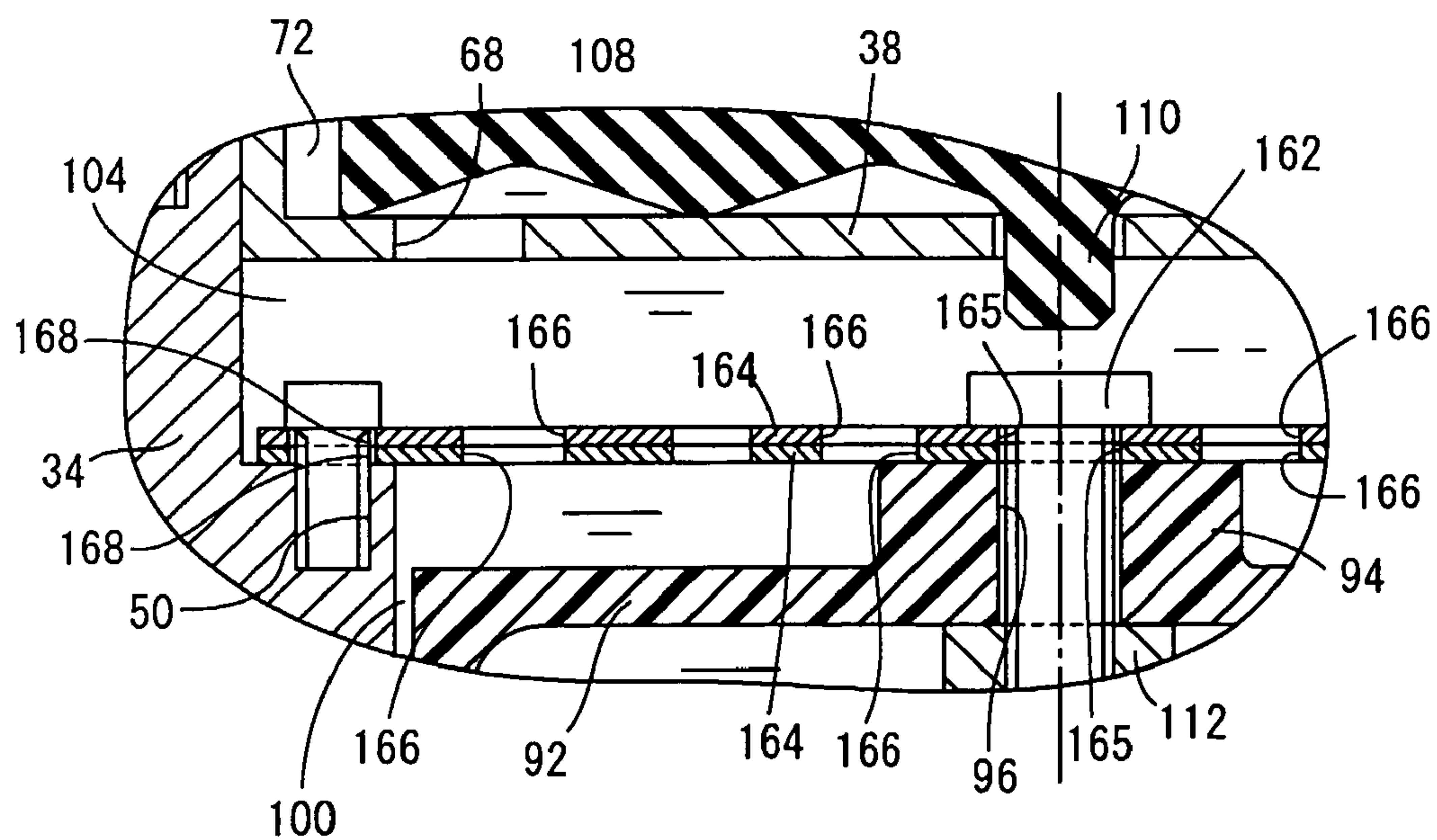


FIG. 10





# FLUID FILLED TYPE VIBRATION DAMPING DEVICE

## INCORPORATED BY REFERENCE

The disclosure of Japanese Patent Application No. 2007-246119 filed on Sep. 21, 2007 and No. 2007-337015 filed on Dec. 27, 2007, each including the specification, drawings and abstract are incorporated herein by reference in their entirety.

## BACKGROUND OF THE INVENTION

### 1. Field of the Invention

The present invention relates to a fluid filled vibration damping device adapted to provide active vibration damping action through control of pressure fluctuations of a pressure receiving chamber that is filled with a non-compressible fluid, the control being carried out in a cycle that corresponds to the frequency of the vibration to be damped.

### 2. Description of the Related Art

In the field of vibration damping devices such as vibration damping linkages or vibration damping supports designed for installation between components that make up a vibration transmission system, one type of known device is a fluid filled type vibration damping device having a first mounting member and a second mounting member linked by a rubber elastic body; a pressure-receiving chamber whose wall is partially defined by the rubber elastic body and an equilibrium chamber whose wall is partially defined by a flexible film, the pressure-receiving chamber and the equilibrium chamber being formed to either side of a partition member and filled with a non-compressible fluid; and an orifice passage connecting the pressure-receiving chamber and the equilibrium chamber. Since this type of fluid filled vibration damping device is able to exhibit vibration damping effect by using flow action, e.g. resonance action, of fluid flowing through the orifice passage, application of such devices in automotive engine mounts and the like is a current topic of interest.

Active type fluid filled vibration damping devices are one type of fluid filled vibration damping device as discussed above. In such an active vibration damping device, typically, another part of the wall of the pressure-receiving chamber will be constituted by an oscillating plate, and an electromagnetic actuator will be disposed to the opposite side of the pressure-receiving chamber, with the oscillating plate between them. A coil member making up part of the electromagnetic actuator is fixedly supported on the second mounting member, and an output member that is subjected to driving force when electrical current is supplied to the coil member is affixed to the oscillating plate. With this arrangement, oscillation by the oscillating plate is actuated through control of current to the coil member with reference to the vibration to be damped, in order to control the vibration damping performance through control of pressure in the pressure-receiving chamber.

The oscillating plate employed in an active vibration damping device of this kind will in some instances be formed from a rubber elastic body for example. However, in order to ensure an effective piston surface area, it is preferable for the plate to be composed of a rigid member of metal, synthetic resin, or the like, as taught in U.S. Pat. No. 6,422,546.

However, in the fluid filled vibration damping device disclosed in U.S. Pat. No. 6,422,546, with the aim of providing the oscillating plate with elastically positioned support while ensuring fluid-tightness on the part of the pressure-receiving chamber, the oscillating plate is linked to the second mounting member via a supporting rubber elastic body of annular

shape. For this reason, there is an anxiety that, owing to permanent set in fatigue of the supporting rubber elastic body, it will be difficult to consistently achieve the desired vibration damping action. Another problem is that oscillation energy of the oscillating plate will be consumed through deformation of the supporting rubber elastic body, and thus power consumption will be high.

Accordingly, in Japanese unexamined Patent Publication No. JP-A-2005-291276, the Applicant proposed a fluid filled vibration damping device incorporating an oscillating plate of piston design. In this fluid filled vibration damping device, a portion of the wall of the pressure-receiving chamber is defined by a cylinder member of hollow round tubular shape, and the output member of the electromagnetic actuator is provided at the distal end thereof in the actuation direction with an oscillating plate of piston shape. A gap is provided between the outside peripheral face of the oscillating plate and the inside peripheral face of the cylinder member, while the oscillating plate is displaceable in the axial direction along the inside peripheral face of the cylinder member. Through appropriate design of the planar dimensions and of the gap between the inside peripheral face of the cylinder member and the outside peripheral face of the oscillating plate, it is possible to control pressure of the pressure-receiving chamber in association with oscillation of the oscillating plate, while ensuring that pressure fluctuations of the pressure-receiving chamber are such that the orifice effect is maintained.

The gap between the inside peripheral face of the cylinder member and the outside peripheral face of the oscillating plate will be sufficiently small so as to inhibit pressure leakage from the pressure-receiving chamber through the gap. Additionally, in order to ensure large planar dimensions of the opposed faces of the oscillating plate and the cylinder member with a view to inhibiting pressure leakage from the pressure-receiving chamber, it will be preferable for the inside peripheral section of the cylinder member and of the outside peripheral section of the oscillating plate to have considerable axial length.

However, where the gap between the cylinder member and the oscillating plate is small and their opposed faces extend for considerable length in the axial direction, there is an anxiety that the oscillating plate will interfere with the inside peripheral face of the cylinder member.

In particular, owing to factors such as the pressure distribution of the pressure-receiving chamber and twisting displacement of the actuator output shaft, the oscillating plate will tend to interfere with the cylinder inside face through twisting displacement in the axial direction. When the oscillating plate experiences displacement in the axial direction while interfering with the cylinder member in this way, not only will the actuation efficiency of the oscillating plate be reduced, but there will also be an anxiety of damage to the opposing faces of the oscillating plate and/or the cylinder member. Furthermore, if seizing should occur, there is an anxiety that electromagnetic actuator may operate improperly or become non-operational, or that noise and vibration may result.

## SUMMARY OF THE INVENTION

It is therefore one object of this invention to provide a fluid filled type active damping device of novel construction which affords stable driving displacement of the oscillating plate, and thereby achieves effective vibration damping action.

The above and/or optional objects of this invention may be attained according to at least one of the following modes of



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the invention. The following modes and/or elements employed in each mode of the invention may be adopted at any possible optional combinations. It is to be understood that the principle of the invention is not limited to these modes of the invention and combinations of the technical features, but may otherwise be recognized based on the teachings of the present invention disclosed in the entire specification and drawings or that may be recognized by those skilled in the art in the light of the present disclosure in its entirety.

A principle of the present invention provides a fluid filled type vibration damping device including: a rubber elastic body elastically connecting a first mounting member and a second mounting member, a partition member supported on the second mounting member; a pressure-receiving chamber whose wall is partly defined by the rubber elastic body; an equilibrium chamber whose wall is partly defined by a flexible film; the pressure-receiving chamber and the equilibrium chamber being formed to either side of the partition member and filled with a non-compressible fluid; a first orifice passage connecting the pressure-receiving chamber and the equilibrium chamber; an oscillating plate defining another part of the wall of the pressure-receiving chamber; and an electromagnetic actuator for actuating oscillation of the oscillating plate. The oscillating plate is constituted by including a cylinder shaped hole having a round tubular inside peripheral face formed in the partition member, and a piston shaped plate accommodated within the cylinder shaped hole with a gap provided between an outside peripheral face of the piston shaped plate and the inside peripheral face of the cylinder shaped hole so that the piston shaped plate is axially displaceable within the cylinder shaped hole, an output member of the electromagnetic actuator is passed through the flexible film and linked to the piston shaped plate, and a plate spring extending in an axis-perpendicular direction is disposed to an opposite side from the electromagnetic actuator with the piston shaped plate therebetween, with the oscillating plate being elastically linked to and supported in an axial direction with respect to the partition member by the plate spring.

In the fluid filled vibration damping device constructed according to the present invention, the oscillating plate at a first side thereof in the axial direction is positioned and supported in the axis-perpendicular direction by the output member of the electromagnetic actuator; and at the other side thereof in the axial direction is positioned and supported in the axis-perpendicular direction by the plate spring. By positioning and supporting the oscillating plate in the axis-perpendicular direction from both sides in the axial direction with respect to the partition member in this way, it is possible to achieve excellent suppressant effect against displacement of the oscillating plate in the axis-perpendicular direction, as well as against displacement in twisting directions.

That is, because the oscillating plate is substantially supported at both sides of its center axis (both sides in the actuation direction of the oscillating plate), the oscillating plate is positioned in proximity to a band of smaller displacement of the medial section rather than at the location of larger displacement of the free end side during tilting of the oscillating plate. For this reason, in addition to displacement in the axis-perpendicular direction, twisting deformation of the oscillating plate will be effectively inhibited as well, preventing it from interfering with the cylinder shape hole.

Moreover, because the oscillating plate is substantially supported at both sides of its center axis, problems caused by interference of the oscillating plate with the cylinder shaped hole can be resolved, while the gap between the outside peripheral face of the oscillating plate (which is constituted by the piston shaped plate) and the inside peripheral face of

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the cylinder shaped hole can be made sufficiently small, and the opposing sections of the piston shaped plate and the cylinder shaped hole can be given sufficient axial length. The effective planar dimensions of the piston shaped plate may be increased thereby, and pressure leakage from the pressure-receiving chamber through the gap may be suppressed, thereby affording efficient and stable pressure control of the pressure-receiving chamber.

Moreover, by making possible a smaller gap between the piston shaped plate and the cylinder shaped hole and greater axial length of the gap, the flow resistance of fluid through the gap can be elevated, preventing pressure fluctuations of the pressure-receiving chamber from escaping into the equilibrium chamber through the gap. This results in effectively producing passive vibration damping action as well.

Furthermore, owing to the use of the plate spring in the present invention, the oscillating plate is allowed to undergo adequate displacement in the axial direction, while at the same time being effectively positioned in the axis-perpendicular direction. Moreover, since the dimension of the plate spring in the axial direction is typically small, it will be possible to avoid problems in terms of ensuring adequate space or larger size in association with installation of the plate spring in the vibration damping device.

According to one preferred mode of the fluid filled vibration damping device of the present invention, the electromagnetic actuator may employ a design whereby the output member is elastically supported with respect to a housing of the electromagnetic actuator by a supporting plate spring that extends in the axis-perpendicular direction. With this arrangement, greater stability of the output member which has been positioned in the axis-perpendicular direction by the supporting plate spring can be utilized to achieve a higher level of reliability in positioning of the oscillating plate in the axis-perpendicular direction.

According to another possible mode of the fluid filled vibration damping device of the present invention, wherein the pressure-receiving chamber is partitioned by a dividing wall member that is disposed in a medial section of the pressure-receiving chamber in order to form to either side of the dividing wall member a first pressure-receiving chamber whose wall is partly defined by the rubber elastic body and a second pressure-receiving chamber whose wall is partly defined by the oscillating plate, and a filter orifice is provided for connecting the first pressure-receiving chamber and the second pressure-receiving chamber. Specifically, in the first pressure-receiving chamber, pressure fluctuations will be produced directly on the basis of elastic deformation of the rubber elastic body at times of input of vibration, whereas the second pressure-receiving chamber will be exposed to pressure fluctuations of the first pressure-receiving chamber through the filter orifice, giving rise to pressure fluctuations in association with input of vibration. Here, where the resonance frequency of fluid flowing through the filter orifice is tuned to the frequency range of problematical vibration that has been targeted for active vibration damping action by the oscillating plate, pressure fluctuations arising in the second pressure-receiving chamber on the basis of actuated oscillation of the oscillating plate will be transmitted efficiently to the first pressure-receiving chamber, utilizing the resonance action etc. of fluid through the filter orifice. The pressure-receiving chamber composed of this first pressure-receiving chamber and second pressure-receiving chamber can thereby be positively and actively controlled, and the desired vibration damping action may be attained with a higher level of effectiveness.



According to yet another possible mode of the fluid filled vibration damping device of the present invention, a second orifice passage is provided connecting the second pressure-receiving chamber and the equilibrium chamber, with the second orifice passage being tuned to a higher frequency range than the first orifice passage, the filter orifice is formed in the dividing wall member, and a movable plate is displaceably disposed in the filter orifice such that pressure of the first pressure-receiving chamber is exerted on a first face of the movable plate while pressure of the second pressure-receiving chamber is exerted on another face of the movable plate. With this arrangement, at times of input of vibration lying in the tuning frequency range of the first orifice passage, the opening of the second oscillating plate on the pressure-receiving chamber side thereof is covered by the movable plate, thus preventing pressure leakage from the pressure-receiving chamber through the second orifice passage and ensuring a sufficient level of fluid flow through the first orifice passage. As a result, vibration damping action based on resonance action of fluid through the first orifice passage will be consistently achieved. Also, at times of input of vibration lying in the tuning frequency range of the second orifice passage, even if the first orifice passage (which has been tuned to a lower frequency range than the second orifice passage) becomes substantially closed off, a sufficient level of fluid flow through the second orifice passage will be ensured on the basis of displacement of the movable plate due to the relative pressure differential between the first pressure-receiving chamber and the second pressure-receiving chamber. Consequently, vibration damping action based on resonance action of fluid through the second orifice passage will be effectively achieved.

Specifically, according to this mode, vibration damping action against vibration of multiple frequency ranges will be effectively afforded based on the flow action, e.g. resonance action, of fluid flowing respectively through the first orifice passage and the second orifice passage. In particular, since the movable plate is disposed in the filter orifice, the movable plate and the filter orifice that is tuned to a higher frequency range than the resonance frequency of the second orifice passage may be realized through a relatively simple structure. Additionally, sufficient space for installing the movable plate will be effectively ensured thereby achieving both improved vibration damping performance and smaller size of the vibration damping device.

The movable plate according to this mode may employ any of a number of designs that regulate pressure fluctuations by inducing displacement of the plate based on a relative pressure differential between the first pressure-receiving chamber and the second pressure-receiving chamber. For example, as taught inter alia in Japanese Unexamined Patent Publication No. JP-A-01-93638, U.S. Pat. No. 7,322,570, or Japanese Unexamined Patent Publication No. JP-A-2006-97823, the movable plate may be positioned held in an unattached state within a prescribed holding area so as to be finely displaceable in the thickness direction within the holding area. Thus, via holes formed in the holding area, pressure of the first pressure-receiving chamber is exerted on one face of the movable plate while pressure of the second pressure-receiving chamber is exerted on the other face of the movable plate, whereby a relative pressure differential between the first pressure-receiving chamber and the second pressure-receiving chamber will be absorbed on the basis of fine displacement of the movable plate within the holding area, and pressure absorption by the movable plate in excess of an allowable displacement level will be prevented. Alternatively, it would be possible to employ a design as taught inter alia in Japanese

Unexamined Patent Publication Nos. JP-A 2000-213586, JP-A-07-71506, or JP-A-11-101294 for example, wherein at least the outside peripheral section of the movable plate is defined by a partition rubber elastic plate, with the partition rubber elastic plate being attached at its outside peripheral edge to the partition member or to the second mounting member thereby fluid-tightly partitioning the first pressure-receiving chamber and the second pressure-receiving chamber so that a relative pressure differential arising between the first pressure-receiving chamber and the second pressure-receiving chamber and exerted on the respective faces of the partition rubber elastic plate will be absorbed on the basis of elastic displacement and/or elastic deformation of the partition rubber elastic plate based on this pressure differential between the first pressure-receiving chamber and the second pressure-receiving chamber, while at the same time preventing large pressure absorption through elastic deformation of the partition rubber elastic plate. Alternatively, it would be possible to employ a design as taught in U.S. Pat. No. 7,188,830, whereby a plurality of elastic projecting portions are disposed on both faces of the movable plate, and the movable plate is constrained in localized fashion by means of these elastic projecting portions being held clasped between the walls of the holding area of the movable plate, with the spaces between the walls of the holding area and those sections of the movable plate devoid of elastic projecting portions defining fluid channels that connect the first pressure-receiving chamber and the second pressure-receiving chamber with one another.

According to yet another possible mode of the fluid filled vibration damping device of the present invention, the cylinder shaped hole is formed in a center section of the partition member so as to extend in a direction of opposition of the pressure-receiving chamber and the equilibrium chamber, with the wall of the equilibrium chamber being defined in part by an outside peripheral section of the partition member about the cylinder shaped hole, and an outside peripheral face of the partition member has a tapering contour decreasing in diameter from a first axial end of a pressure-receiving chamber side thereof towards another axial end on an equilibrium chamber side. According to this mode, variable capacity of the flexible film in the equilibrium chamber will be efficiently ensured, and freedom in design of the flexible film will be improved, thereby affording further improvement in tuning of the desired vibration damping action.

According to yet another possible mode of the fluid filled vibration damping device of the present invention, a plurality of plate springs are disposed in a stacked structure by being juxtaposed in a direction of actuation of the oscillating plate. Specifically, while one conceivable method for increasing the oscillation frequency of the oscillating plate would be to increase the thickness dimension of the plate spring to make it more rigid for example, making the plate spring thicker in this way will tend to result in higher stress and significant strain. In a plate spring, which experiences appreciable metal fatigue due to repeated elastic deformation experienced during actuation of the oscillating plate, it is important to minimize strain in order to ensure endurance. Accordingly, as taught in this mode, where a stacked structure composed of a plurality of juxtaposed plate springs is employed, the plate spring can be made more rigid while at the same time reducing stress transmission and avoiding significant strain. For this reason, enduring performance of the oscillating plate may be ensured, while further improving the degree of freedom in tuning of the oscillation frequency.

According to still another possible mode of the fluid filled vibration damping device of the present invention, a lightening



ing section is formed in each plate spring, and a plurality of plate springs are juxtaposed with the lightening sections communicating with one another. By so doing, a zone between the plate springs and the oscillating plate will communicate via the lightening sections with a fluid-filled zone whose wall is partly defined by the rubber elastic body. For this reason, the pressure-receiving chamber can be constituted by a zone between the plate springs and the oscillating plate in addition to the fluid-filled zone to the inside of the rubber elastic body, thereby effectively ensuring adequate capacity of the pressure-receiving chamber. Moreover, when the plate springs induce elastic deformation within the pressure-receiving chamber, the fluid resistance of the plate springs will be lower due to the presence of the lightening sections, thereby reducing energy loss associated with deforming of the plate springs, and hence with actuating oscillation of the oscillating plate. Furthermore, since the spring characteristics of the plate springs can now be tuned through appropriate design modification of the shape, size, number etc. of the lightening sections in addition to design modification of the shape, size, etc. of the plate springs, a higher degree of freedom in tuning of spring characteristics is afforded thereby.

#### BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and/or other objects, features and advantages of the invention will become more apparent from the following description of a preferred embodiment with reference to the accompanying drawings in which like reference numerals designate like elements and wherein:

FIG. 1 is a vertical cross sectional view of a fluid filled type vibration damping device in the form of an automotive engine mount according to one embodiment of the present invention;

FIG. 2 is a top plane view of a partition member of the engine mount of FIG. 1;

FIG. 3 is a cross sectional view taken along line 3-3 of FIG. 2;

FIG. 4 is a top plane view of a partition member body of FIG. 2;

FIG. 5 is a top plane view of an oscillating plate of the engine mount of FIG. 1;

FIG. 6 is a cross sectional view of the oscillating plate taken along line 6-6 of FIG. 5;

FIG. 7 is a top plane view of a supporting plate spring of the engine mount of FIG. 1;

FIG. 8 is an enlarged cross sectional view taken along line 8-8 of FIG. 7;

FIG. 9 is a top plane view of a part of a plate spring of the engine mount of FIG. 1; and

FIG. 10 is an enlarged view in vertical cross section of a part of an engine mount of construction according to another embodiment of the present invention.

#### DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Referring first to FIG. 1, there is depicted an automotive engine mount 10 according to one embodiment of a fluid-filled type vibration damping device of the present invention. This engine mount 10 has a construction wherein a first mounting member 12 of metal and a second mounting member 14 of metal are linked by a main rubber elastic body 16. The first mounting member 12 is adapted to be mounted onto the vehicle's power unit (not shown), and the second mounting member 14 is adapted to be mounted onto an automobile

body (not shown). The power unit is thereby elastically supported on the vehicle body via the intervening engine mount 10.

Whereas FIG. 1 depicts the engine mount 10 in isolation prior to installation in a vehicle, with the engine mount 10 installed in the vehicle, distributed load of the power unit will be input in the mount axial direction (the vertical direction in FIG. 1), thereby inducing displacement of the first mounting member 12 and the second mounting member 14 in the direction closer together in the mount axial direction, whereupon the main rubber elastic body 16 elastically deforms. In this installed state, principle vibration targeted for damping will be input approximately in the mount axial direction. In the description hereinbelow, unless indicated otherwise, vertical direction refers to the vertical direction in FIG. 1.

More specifically, the first mounting member 12 has an inverted bottomed round tubular shape or round post shape. A screw hole 18 which opens onto the upper end face is provided in the center section of the first mounting member 12. The first mounting member 12 is attached securely to the power unit by screw-fastening a member on the power unit side (not shown) to the screw hole 18 using a fastening bolt.

The second mounting member 14 has a large-diameter, generally stepped round tubular shape, with a small-diameter portion 22 extending upward from the inside peripheral edge of a shoulder portion 20 of annular plate shape, and a large-diameter portion 24 extending downward from the outside peripheral edge of the shoulder portion 20. The axial dimension of the small-diameter portion 22 is longer than the axial dimension of the large-diameter portion 24.

The first mounting member 12 and the second mounting member 14 are positioned coaxially with one another, with the first mounting member 12 positioned facing at a prescribed distance away in the axial direction the opening at the small-diameter portion 22 end of the second mounting member 14. The main rubber elastic body 16 is interposed between the first mounting member 12 and the second mounting member 14.

The main rubber elastic body 16 is a thick rubber elastic body of generally truncated conical shape. In the center portion of the lower end of the main rubber elastic body 16, there is formed a large-diameter recess 26 of inverted conical or semispherical shape opening downward. A section of the first mounting member 12 extending to its lower end from its axially medial portion is vulcanization bonded to the upper end of the main rubber elastic body 16 so as to be embedded therein, while the inside peripheral face of the small-diameter portion 22 of the second mounting member 14, at a section thereof extending to its axially medial portion from its upper end section, is juxtaposed against and vulcanization bonded to the outside peripheral face of the lower end of the main rubber elastic body 16. The main rubber elastic body 16 is thereby constituted as an integrally vulcanization molded component that integrally incorporates the first mounting member 12 and the second mounting member 14, and one of the openings of the second mounting member 14 (at top in FIG. 1) is sealed off fluid-tightly by the main rubber elastic body 16. The inside peripheral face of the small-diameter portion 22 of the second mounting member 14 is sheathed entirely from its axially medial section to its lower end section by a thin rubber seal layer 28 that is integrally formed with the main rubber elastic body 16. The rim of the open end of the large-diameter recess 26 in the main rubber elastic body 16 is situated inward in the axis-perpendicular direction from the inside peripheral face of the rubber seal layer 28, so that an



annular step portion **30** of annular shape is formed in the boundary section between the main rubber elastic body **16** and the rubber seal layer **28**.

A partition member **32** is attached in the opening section of the second mounting member **14** on its axial lower side. The partition member **32** overall has a generally round block shape, and includes a partition member body **34**, a first dividing wall plate **36** and a second dividing wall plate **38**. In this embodiment, the partition member **32** is made of metal material such as aluminum alloy or steel, but it could also be made from rigid synthetic resin material or the like.

As depicted in FIGS. 2 to 4 as well, an outer flanged portion **40** of large-diameter annular shape is integrally formed at the upper edge section of the partition member body **34**. The outside peripheral face of the partition member body **34** has a tapered shape gradually decreasing in outside diameter dimension from top to bottom.

A circular center hole **42** is formed extending in the axial direction through the center section of the partition member body **34** so as to penetrate the upper and lower end faces of the partition member body **34**. A step portion **44** of annular shape is formed in the peripheral wall of the center hole **42** in its generally axial center section, with the diameter dimension of the center hole **42** in its upper section to one side of the step portion **44** being larger compared to the diameter dimension in its lower section. A cylinder shaped hole **46** according to this embodiment is defined by this lower section of the center hole **42**. An inner flanged portion **48** is integrally formed at the lower opening section of the cylinder shaped hole **46**. A plural number of screw holes **50** are disposed prescribed distances apart in the circumferential direction, in the step portion **44** and around the upper rim of the center hole **42**. The diametrically medial section or outer peripheral section of the outer flanged portion **40** is perforated in the thickness direction (the vertical in FIG. 1) by a connecting window **52**. As will be apparent from the above description, the cylinder shaped hole **46** is formed so as to extend in the axial direction through the center section of the partition member **32** (the partition member body **34**), and the outer peripheral section of the partition member **32** around the cylinder shaped hole **46** is defined by a tapered shape of decreasing diameter from a first axial end (at top in FIG. 1) to the other.

A block shaped portion **54** is disposed projecting diametrically outward from a single location along the circumference of the peripheral wall section of the partition member body **34**, and a connecting passage **56** extends in tunnel form through the block shaped portion **54**. The connecting passage **56** extends continuously with unchanging oblong cross section in the diametrical direction through the partition member body **34**, with a first end (face) thereof opening onto the peripheral wall face of the center hole **42** of the partition member body **34** at a location above the step portion **44**, and with the other end (face) opening onto the diametrically outward end face of the block shaped portion **54**.

The first dividing wall plate **36** has a shallow, generally circular saucer shape whose base portion is penetrated by through-holes **58** composed of a plurality of small holes; and a rimming portion **60** of annular shape is integrally formed at its upper lip. The rimming portion **60** extends parallel to the base portion of the first dividing wall plate **36**, at a location above the base portion. The outside diameter dimension of the base portion of the first dividing wall plate **36** is large in comparison with the diameter dimension of the large-diameter section at the upper side of the center hole **42** of the partition member body **34**, and insertion holes **64** are formed

penetrating the outside peripheral section of the base portion at locations corresponding to the screw holes **50** of the partition member body **34**.

Meanwhile, the second dividing wall plate **38** has a shallow, generally bottomed cylindrical shape, with a large-diameter outer flanged portion **66** formed at the lip of the opening. In other words, the second dividing wall plate **38** has the form of a thin circular disk shape with a circular recess formed in its center section. The outside diameter dimension of the outer flanged portion **66** is approximately identical to the outside diameter dimension of the outer flanged portion **40** of the partition member body **34**, and is larger in comparison with the outside diameter dimension of the rimming portion **60** of the first dividing wall plate **36**. The outside diameter dimension of the peripheral wall of the second dividing wall plate **38** is slightly smaller than the diameter dimension of the large-diameter section at the upper side of the center hole **42** of the partition member body **34**. Furthermore, the axial length of the peripheral wall of the second dividing wall plate **38** is smaller in comparison with the axial length of the large-diameter section. Through-holes **68** composed of a plurality of small holes are formed penetrating the base portion of the second dividing wall plate **38**. Additionally, insertion holes **70** are formed penetrating the diametrically medial section or inside peripheral section of the outer flanged portion **66**, at locations corresponding to the screw holes **50** of the partition member body **34** and to the insertion holes **64** of the first dividing wall plate **36**.

The peripheral wall of the second dividing wall plate **38** is slipped into the upper opening section of the center hole **42** of the partition member body **34**, and the outer flanged portion **66** of the second dividing wall plate **38** is juxtaposed against the outer flanged portion **40** of the partition member body **34**. Furthermore, the outside peripheral section of the base of the first dividing wall plate **36** is juxtaposed against the diametrical inside peripheral section or medial section of the outer flanged portion **66** of the second dividing wall plate **38**, while the screw holes **50** of the partition member body **34**, the insertion holes **70** of the second dividing wall plate **38**, and the insertion holes **64** of the first dividing wall plate **36** are aligned overlapping one another in the axial direction. Fastening bolts are then passed through the insertion holes **64**, **70** in the first and second dividing wall plates **36**, **38**, and fastened by screwing into screw holes **50** of the partition member body **34**. The partition member **32** constituted thereby has a form in which the upper opening of the center hole **42** of the partition member body **34** has been covered by the first and second dividing wall plates **36**, **38**. The base portion of the second dividing wall plate **38** and the step portion **44** of the center hole **42** in the partition member body **34** are now positioned in opposition a prescribed distance apart in the axial direction.

The rimming portion **60** of the first dividing wall plate **36** and the outer flanged portion **66** of the second dividing wall plate **38** are positioned in opposition a prescribed distance apart in the axial direction, with the lower end face of the rimming portion **60**, the outside peripheral face of the peripheral wall of the first dividing wall plate **36**, and the upper end face of the outer flanged portion **66** cooperating to define a peripheral groove **62** having a cross section that opens with slot contours diametrically outward in the outside peripheral section of the partition member **32**, and extends continuously all the way around its circumference.

Furthermore, by covering the opening section of the second dividing wall plate **38** with the base portion of the first dividing wall plate **36**, a circular zone **72** that extends with generally unchanging circular cross section in the axial direc-



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tion is formed between the center of the base portion of the first dividing wall plate 36 and the center portion of the second dividing wall plate 38.

The partition member 32 of the above design is inserted in the axial direction into the second mounting member 14 from its bottom opening, and the rimming portion 60 of the first dividing wall plate 36 is juxtaposed against the annular step portion 30 of the main rubber elastic body 16, while the outside peripheral section of the outer flanged portion 66 of the second dividing wall plate 38 is juxtaposed against the shoulder portion 20 via the intervening rubber seal layer 28 of the second mounting member 14. With this arrangement, the inserted end of the partition member 32 in the axial direction is regulated with respect to the second mounting member 14.

A diaphragm 74 (the flexible film) is disposed below the partition member 32. The diaphragm 74 is formed from a thin circular rubber film having ample slack. A fastener fitting 76 is vulcanization bonded to the outside peripheral edge of the diaphragm 74. The fastener fitting 76 has a design with an inner flanged portion that projects diametrically inward integrally disposed at the lower end section of a large-diameter ring. The diaphragm 74 is vulcanization bonded at its outside peripheral edge to the inside peripheral edge of the fastener fitting 76, while a thin seal rubber layer 78 that is integrally formed with the diaphragm 74 is vulcanization bonded over generally the entire inside peripheral face of the fastener fitting 76.

The fastener fitting 76 is, slipped inside the second mounting member 14 in the axial direction from the opening on its lower side (the large-diameter portion 24 side), and the upper edge of the fastener fitting 76 is then juxtaposed in the axial direction against the inside peripheral section of the shoulder portion 20 of the second mounting member 14 via the intervening seal rubber layer 78, while the inside peripheral edge on the lower side of the fastener fitting 76 is juxtaposed in the axial direction against the outside peripheral section of the outer flanged portion 40 of the partition member body 34 via the intervening seal rubber layer 78.

Further, a bracket member 80 of round tubular shape is fastened fitting externally about the second mounting member 14. This bracket member 80 is utilized to fasten the partition member 32 and the diaphragm 74 to the second mounting member 14. Specifically, the bracket member 80 includes a middle tube fitting 82 having a thick-walled generally round tubular shape and end plate fittings 84a, 84b of annular plate shape that are juxtaposed against the axial ends of the middle tube fitting 82. The fittings 82, 84a, 84b are mated in the axial direction and fastened together with bolts. With the shoulder portion 20 of the second mounting member 14 and the fastener fitting 76 of the diaphragm 74 inserted axially between the upper end plate fitting 84a and the middle tube fitting 82, the bracket member 80 is fastened to the second mounting member 14 by bolting together the end plate fitting 84a and the middle tube fitting 82. In association with bolting together the end plate fitting 84a and the middle tube fitting 82, the shoulder portion 20 of the second mounting member 14 and the fastener fitting 76 is positioned clamped in the axial direction, with the rimming portion 60 of the first dividing wall plate 36 and the annular step portion 30 of the main rubber elastic body 16, the outside peripheral section of the outer flanged portion 66 of the second dividing wall plate 38 and the diametrically inside peripheral section or medial section of the shoulder portion 20 of the second mounting member 14, and the upper end section of the fastener fitting 76 and the outside peripheral section of the shoulder portion 20 respectively juxtaposed fluid-tightly via the intervening rubber seal layers 28, 78 etc. By so doing, through fastening of

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the bracket member 80 to the second mounting member 14 the partition member 32 and the diaphragm 74 is fixedly attached to the second mounting member 14, while the lower opening of the second mounting member 14 is blocked off fluid-tightly by the partition member 32 and the diaphragm 74. By then fastening the bracket member 80 to a component on the vehicle body side (not shown), the second mounting member 14 is fixedly mounted onto the vehicle body.

By thusly attaching the partition member 32 and the diaphragm 74 to the integrally vulcanization molded component of the main rubber elastic body 16 incorporating the first and second mounting members 12, 14, a pressure-receiving chamber 86 whose wall is partly defined by the main rubber elastic body 16 and which gives rise to pressure fluctuations at times of vibration input is defined to a first axial side of the partition member 32 (at top in FIG. 1), within the area of the large-diameter recess 26 of the main rubber elastic body 16 that has been blocked off by the partition member 32. To the other axial side of the partition member 32 (at bottom in FIG. 1) there will be formed an equilibrium chamber 88 whose wall is partly defined by the diaphragm 74 and which readily allows change in volume. The pressure-receiving chamber 86 and the equilibrium chamber 88 are filled with a non-compressible fluid. Water, an alkylene glycol, a polyalkylene glycol, silicone oil, or the like may be employed as the sealed non-compressible fluid, but with a view to effectively achieving vibration damping action based on flow action, e.g. resonance action, of the fluid, it is especially preferable to use a low-viscosity fluid of 0.1 Pa·s or lower. Sealing of the non-compressible fluid within the pressure-receiving chamber 86 and the equilibrium chamber 88 may be accomplished advantageously, for example, by attaching the partition member 32 and the diaphragm 74 to the main rubber elastic body 16 incorporating the first and second mounting members 12, 14 while these components are submerged in the non-compressible fluid. From the above discussion it is appreciated that the wall of the equilibrium chamber 88 is partly defined by the tapered outside peripheral section of the partition member 32 (the partition member body 34) around the cylinder shaped hole 46.

In association with the partition member 32 being attached to the second mounting member 14, the open section of the peripheral groove 62 of the partition member 32 is juxtaposed fluid-tightly against the inside peripheral face of the second mounting member 14 via the intervening rubber seal layer 28 that sheathes the second mounting member 14, so that the peripheral groove 62 is closed off fluid-tightly. The inside peripheral face of the second mounting member 14 and the walls of the peripheral groove 62 are thereby cooperate to define a first orifice passage 90 that extends for a prescribed length in the circumferential direction through the outside peripheral section of the partition member 32. A first end of this first orifice passage 90 connects to the pressure-receiving chamber 86 via a connecting window (not shown) that penetrates the peripheral wall of the first dividing wall plate 36, while the other end of the first orifice passage 90 connects to the equilibrium chamber 88 through a connecting window penetrating the second dividing wall plate 38 and the connecting window 52 of the partition member body 34, which windows have been aligned with one another in axial direction. The pressure-receiving chamber 86 and the equilibrium chamber 88 thereby communicate with each other through the first orifice passage 90, allowing fluid flow between the two chambers 86, 88 through the first orifice passage 90.

An oscillating plate 92 composed of a piston shaped plate is disposed in the cylinder shaped hole 46 of the partition member 32. As depicted in FIGS. 5 and 6, the oscillating plate



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92 has a thin, generally circular disk shape, and is made of rigid synthetic resin material, metal, or the like. A boss shaped projection 94 having a small-diameter cylindrical shape projects upward from the center section of the oscillating plate 92, and the borehole of the boss shaped projection 94 opens onto the lower end face of the oscillating plate 92 so that an insertion hole 96 is formed on the center axis of the oscillating plate 92. Additionally, a rim shaped projection 98 of generally round cylindrical shape is formed on the outside peripheral edge of the oscillating plate 92, projecting downward in the axial direction.

The oscillating plate 92 and the cylinder shaped hole 46 are arranged coaxially, with the rim shaped projection 98 of the oscillating plate 92 positioned along the peripheral wall of the cylinder shaped hole 46 of the partition member 32. The oscillating plate 92 is positioned in opposition to and a prescribed distance away in the axial direction from the base portion of the second dividing wall plate 38 which covers the upper opening of the center hole 42 of the partition member body 34. Here, small gap 100 is formed about the entire perimeter between the peripheral wall of the cylinder shaped hole 46 and the outside peripheral section of the oscillating plate 92 having the rim shaped projection 98, and due to the presence of this gap 100, an appropriate level of axial displacement of the oscillating plate 92 is allowed. While no particular limitation is imposed as to whether fluid flow etc. can arise through this gap 100, in this embodiment, the gap 100 is small enough that substantially no fluid flow etc. will take place through it. As a result, the lower opening of the center hole 42 of the partition member body 34 will be substantially blocked off by the oscillating plate 92.

The zone between the second dividing wall plate 38 and the oscillating plate 92 in the partition member 32 intercommunicates with the pressure-receiving chamber 86 through the through-holes 58, 68 that penetrate the first and second dividing wall plates 36, 38 and through the circular zone 72 between the first dividing wall plate 36 and the second dividing wall plate 38, and this zone is filled with the same non-compressible fluid as the pressure-receiving chamber 86. Specifically, through the through-holes 58, 68 and the circular zone 72 the zone between the oscillating plate 92 and the second dividing wall plate 38 is subject to pressure fluctuations arising in the pressure-receiving chamber 86, and thus the zone functions as part of the pressure-receiving chamber 86. As will be appreciated from the description above, in the pressure-receiving chamber 86, the oscillating plate 92 defines another part of the wall different from that defined by the main rubber elastic body 16.

In other words, to a first side of the first and second dividing wall plates 36, 38 (at top in FIG. 1) of the partition member 32, there is formed a first pressure-receiving chamber 102 whose wall is partly defined by the main rubber elastic body 16, while to the other side of the first and second dividing wall plates 36, 38 (at bottom in FIG. 1) of the partition member 32, there is formed a second pressure-receiving chamber 104 whose wall is partly defined by the oscillating plate 92. The pressure-receiving chamber 86 incorporates this first pressure-receiving chamber 102 and second pressure-receiving chamber 104 in its design. It will be appreciated from the above description that the dividing wall member dividing the pressure-receiving chamber 86 incorporates the first dividing wall plate 36 and the second dividing wall plate 38 in its design. Additionally, the filter orifice through which the first pressure-receiving chamber 102 and the second pressure-receiving chamber 104 intercommunicate incorporates the

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through-holes 58, 68 that have been formed in the first and second dividing wall plates 36, 38 and the circular zone 72 in its design.

In this embodiment in particular, the resonance frequency of fluid flowing through the filter orifice that incorporates the aforementioned through-holes 58, 68 and the circular zone 72 has been tuned to a high frequency range on the order of 80 to 100 Hz corresponding to medium- or high-speed rumble which has been targeted for active vibration damping by the oscillating plate 92.

The connecting passage 56 that has been formed in the partition member body 34 connects at a first end thereof to the second pressure-receiving chamber 104, while the other end of the connecting passage 56 connects to the equilibrium chamber 88. That is, the connecting passage 56 constitutes a second orifice passage 106 connecting the second pressure-receiving chamber 104 and the equilibrium chamber 88 to one another and allowing flow of fluid between the two chambers 88, 104 through the second orifice passage 106.

In this embodiment in particular, the resonance frequency of fluid flowing through the first orifice passage 90 is tuned, for example, so as to produce effective vibration damping action (high attenuating action) against vibration in a low-frequency range of about 10 Hz corresponding to engine shake, on the basis of resonance action of the fluid. Meanwhile, the resonance frequency of fluid flowing through the second orifice passage 106 is tuned, for example, so as to produce effective vibration damping action against vibration in a medium-frequency range of about 20 to 40 Hz corresponding to idling vibration or low speed rumble, on the basis of resonance action of the fluid. That is, the tuning frequency of the second orifice passage 106 is set to a higher frequency range than the tuning frequency of the first orifice passage 90, and the tuning frequency of the filter orifice defined by the aforementioned through-holes 58, 68 and the circular zone 72 is set to a higher frequency range than the first and second orifice passages 90, 106. Tuning of the first orifice passage 90, the second orifice passage 106, and the filter orifice may be accomplished, for example, through adjustment of the passage length and passage cross sectional area of the orifice passages while giving consideration to characteristic values based on the rigidity of the walls of the pressure-receiving chamber 86 and the equilibrium chamber 88, i.e. on the levels of elastic deformation by the main rubber elastic body 16 and by the diaphragm 74 corresponding to pressure change levels necessary to produce a certain change in unit volume of the chambers 86, 88. Typically, the frequency at which the phase of pressure fluctuations transmitted through the orifice passage changes and assumes the resonance state can be understood as the tuning frequency of the orifice passage.

A movable plate 108 is positioned housed within the circular zone 72 of the partition member 32. This movable plate 108 has a generally circular disk shape that is slightly smaller than the circular zone 72, and is made of a rubber elastic body. A gap is formed all the way around the circumference between the peripheral wall of the circular zone 72 (i.e. the peripheral wall second dividing wall plate 38) and the outside peripheral edge of the movable plate 108. The thickness dimension of the movable plate 108 is smaller in comparison with the axial dimension of the circular zone 72. The pressure of the first pressure-receiving chamber 102 is exerted on a first face of the movable plate 108 (at top in FIG. 1) via the through-holes 58 in the first dividing wall plate 36, while the pressure of the second pressure-receiving chamber 104 is exerted on the other face of the movable plate 108 (at bottom in FIG. 1) via the through-holes 68 in the second dividing wall plate 38. The movable plate 108 is thereby constituted so as to



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be displaceable in the axial direction within the circular zone 72 on the basis of a relative pressure differential between the first pressure-receiving chamber 102 and the second pressure-receiving chamber 104.

Guide shaft portions 110, 110 are disposed in the center section of the movable plate 108 so as to project outward to either side in the axial direction. With the movable plate 108 positioned housed within the circular zone 72, each guide shaft portion 110 is displaceably inserted into an insertion hole provided in the center section of the first dividing wall plate 36 which defines the upper wall of the circular zone 72 and of the second dividing wall plate 38 which defines its lower wall, thereby positioning the movable plate 108 in the axis-perpendicular direction with respect to the circular zone 72, and approximately aligning the center axis of the movable plate 108 with the center axis of the engine mount 10 (the mount axis). Since the movable plate 108 has a corrugated shape on either face, due to the smaller striking area of the movable plate 108 against the first dividing wall plate 36 and the second dividing wall plate 38, noise is reduced, while at the same time ensuring large effective surface area of the movable plate 108 so that pressure of the first and second pressure-receiving chambers 102, 104 is efficiently exerted on the movable plate 108.

In this embodiment in particular, the resonance frequency of the movable plate 108 is tuned to a medium frequency range, such as idling vibration or medium speed rumble, that lies within the same range as the tuning frequency range of the second orifice passage 106, and is set to a lower frequency range compared to the high range of oscillation frequency of the oscillating plate 92 and the resonance frequency of the filter orifice.

A connector rod 112 is vulcanization bonded to the center section of the diaphragm 74. The connector rod 112 is a rigid rod shaped member that extends in the axial direction, and is provided at a first axial end (at top in FIG. 1) with a screw hole 114 that opens onto the first end face; its other side in the axial direction is elongated in the axial direction and is provided at its distal end section with a male thread portion 116. A rimming portion 118 which flares diametrically outward is integrally formed in the axially medial section of the connector rod 112, and the center section of the diaphragm 74 is vulcanization bonded onto substantially the entire surface of the rimming portion 118. The connector rod 112 body is thereby vulcanization bonded to the diaphragm 74 so as to penetrate through the center section of the diaphragm 74.

An electromagnetic actuator 120 that actuates oscillation of the oscillating plate 92 is positioned below the second mounting member 14. The electromagnetic actuator 120 in this embodiment employs a known design, and since it would be possible to employ a design like that disclosed for example in Japanese Unexamined Patent Publication No. JP-A-2003-339145, the actuator need not be discussed in detail herein except to note that a yoke member 124 which constitutes the stator is positioned spaced apart to the outside peripheral side of a movable member 122 which constitutes the slider. Coils 126, 127 and permanent magnets 128 are attached to the yoke member 124, and through the action of electromagnetic force generated between the movable member 122 and the yoke member 124 when electrical current flows to the coils 126, 127, the movable member 122 is actuated in the axial direction relative to the stator (the yoke member 124).

Specifically, the yoke member 124 is formed of a laminated steel sheet made of ferromagnetic material, and while not depicted explicitly in the drawings, has a design in which a pair of magnetic pole portions 130, 130 project in opposition along an axis-perpendicular direction on the inside peripheral

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face from a ring shaped outer peripheral magnetic path. The coils 126, 127 are installed on the pair of magnetic pole portions 130, 130 by being wound about the perimeter at their respective projecting distal end sections. Each of the coils 126, 127 is sheathed by an electrical insulating layer 132. Further, four permanent magnets 128 that are superposed along the lamination direction of the laminated steel sheet are affixed to the inside peripheral face of the pair of magnetic pole portions 130, 130. The inside peripheral face of each of the permanent magnets 128 is magnetized to one of S and N polarity, while the outside peripheral face of each of the permanent magnets 128 is magnetized to the other of S and N polarity. The four permanent magnets 128 are arranged with their magnetic poles differing from one another in the superposition direction. In this embodiment, four permanent magnets 128 are disposed in each coil 126, 127, accommodated within the approximate center in the axial direction.

The housing 136 of the electromagnetic actuator 120 is positioned to the outside peripheral side of the yoke member 124. The design of the housing 136 incorporates a large-diameter tubular portion 138 that extends in the axial direction, and an annular plate portion 140 of generally annular plate shape that is fastened to the upper end section of the tubular portion 138 and spreads out in the circumferential direction. The yoke member 124, which is housed within the tubular portion 138 while sandwiched in the axial direction by a pair of outer tubular washers (spacers) 141, 141, is fixedly supported suspended from the annular plate portion 140 by passing elongated fastening bolts 139 through it in the axial direction and then securing nuts 135 onto the distal ends thereof.

The housing 136 is also provided with a lead wire 142. A first end of the lead wire 142 connects to the coils 126, 127 inside the housing 136, while the other end of the lead wire 142 extends out from the outside peripheral face of the housing 136 and hooks up to a power supply 144. This enables the coils 126, 127 to be supplied with electrical current from the power supply 144 through the lead wire 142. As the power supply 144, it would be possible to employ the installed power supply for the car's electrical system, for example.

Meanwhile, the movable member 122 is disposed to the inside of the yoke member 124. The design of the movable member 122 incorporates an actuating rod 154 of elongated tube shape, a plurality of magnetic plates 155, and a plurality of inner tubular washers (spacers) 156 of round tubular shape larger in diameter than the actuating rod 154. A collar 158 that flares diametrically outward is integrally formed in the upper part of the actuating rod 154.

The magnetic plates 155 are composed of ferromagnetic material having plate shape, with an insertion hole formed in the center. The inside diameter dimension of this insertion hole is slightly larger than the actuating rod 154. The length of magnetic plates 155 at their two end edges (length in the left-right direction in FIG. 1) is shorter by a prescribed amount than the distance between the opposing faces of the pair of permanent magnets 128, 128 that have been positioned in opposition in the axis-perpendicular direction. The outside diameter dimension of the inner tubular washers (spacers) 156 is smaller than the distance between the opposing faces of the coils 126, 127 in the axis-perpendicular direction.

With a pair of assemblies, each composed of three magnetic plates 155 stacked in the axial direction, positioned in opposition in the axial direction to either side of the center inner tubular washer 156b, and with inner tubular washers 156a, 156c juxtaposed from outside in the axial direction against the respective stacked magnetic plate 155 assemblies, the magnetic plates 155 and the inner tubular washers 156a, b,



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*c* are slipped about the outside of the actuating rod 154. The magnetic plates 155 are arranged thereby so as to project outward in the axis-perpendicular direction from the actuating rod 154, with the axis-perpendicular projecting distal ends (outside peripheral end edges) of the magnetic plates 155 positioned in the axially medial section of the respective coils 126, 127, and positioned in opposition to the permanent magnets 128 in the axis-perpendicular direction. The axial distance separating the pair of assemblies of three magnetic plates 155 is smaller than the inside diameter dimension of the coils 126, 127.

The end of the connector rod 112 on the opposite side of the rimming portion 118 from the screw hole 114 is slipped into the actuating rod 154, and a ring shaped spacer 159 is installed fitting about the outside of the male thread portion 116 located at the distal end section of the connector rod 112 which is positioned projecting axially outward from the actuating rod 154, and a fastening nut 160 is then threaded and fastened thereon. Due to the fastening force of the fastening nut 160 that has been threaded onto the connector rod 112, the magnetic plates 155 and the inner tubular washers 156 is clamped in the axial direction between the fastening nut 160 and the collar 158 of the actuating rod 154, and fastened to the actuating rod 154.

Furthermore, a plurality of supporting plate springs 146 are disposed between the movable member 122 and the yoke member 124. As depicted in FIGS. 7 and 8, the supporting plate springs 146 have thin annular disk shape made of spring steel or the like, with a center hole 147 of circular shape formed in the center section. As lightening sections, a plurality of slits 148 are formed in the diametrically medial section of the supporting plate spring 146, and it will be possible to adjust the substantial effective spring length of the supporting plate spring 146 and to tune its spring characteristics through appropriate design modification of the shape, size, number and/or locations of these slits 148. The outside peripheral section of the supporting plate spring 146 is perforated by a plurality of bolt insertion holes 150. In this embodiment in particular, the plurality of slits 148 and the plurality of bolt insertion holes 150 are respectively given identical form and are respectively formed at equidistant intervals in the circumferential direction, thereby eliminating the need to align the supporting plate springs 146 in the circumferential direction.

At least one of these supporting plate springs 146 is positioned to one axial side (at top in FIG. 1) of the coil 126, 127. With the actuating rod 154 passed through the center hole 147 of the supporting plate spring 146 and with the inside peripheral section of the supporting plate spring 146 secured clamped between the collar 158 of the actuating rod 154 and the inner tubular washer 156, is supported thereby on the movable member 122. Additionally, at least one more of the supporting plate springs 146 is positioned to the other axial side (at bottom in FIG. 1) of the coil 126, 127. With the actuating rod 154 passed through the center hole 147 of the supporting plate spring 146 and with the inside peripheral section of the supporting plate spring 146 secured clamped between the inner tubular washer 156 and the spacer 159, is supported thereby on the movable member 122.

Fastening bolts 139 for securing the yoke member 124 to the housing 136 are passed through each of the bolt insertion holes 150 that have been formed in the outside peripheral section of each of the supporting plate springs 146. The outside peripheral section of the supporting plate springs 146 are clasped, via a ring shaped washer 161, between one of the outer tubular washers 141 and the annular plate portion 140, and via another ring shaped washer 161, between the other outer tubular washer 141 and the nuts 135. The outside

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peripheral sections of the supporting plate springs 146 are secured clamped in the axial direction, and supported on the yoke member 124 through screw fastening of the fastening bolts 139 and the nuts 135.

With this arrangement, the movable member 122 is elastically supported at both axial sides by the supporting plate springs 146 which extend in the axis-perpendicular direction, and the movable member 122 is positioned concentrically with the housing 136 incorporating the yoke member 124, and is supported displaceably in the axial direction to the inside of the yoke member 124. Additionally, the pair of assemblies composed of three magnetic plates 155 stacked adjacently in the axial direction is positioned in opposition to the permanent magnets 128 of the yoke member 124 across a small gap in the axis-perpendicular direction.

In this embodiment in particular, the supporting plate springs 146 which support the movable member 122 at both of its axial sides are deployed in sets of two situated to either side in the axial direction, and are juxtaposed fluid-tightly against the movable member 122 in the axial direction. As the slits 148 which have been formed in each of the supporting plate springs 146 are situated at projected locations in the axial direction, the slits 148 will overlap so as to communicate with one another.

A saucer shaped cover member 163 is attached to the opening section of the tubular portion 138 of the housing 136 so as to cover the opening section of the tubular portion 138. The movable member 122 and the yoke member 124 situated inside the electromagnetic actuator 120 is thereby protected from the outside by the tubular portion 138 and the cover member 163.

The lower end face of the outside peripheral section of the annular plate portion 140 of the housing 136 in the electromagnetic actuator 120 is juxtaposed against the upper end face of the inside peripheral section of the lower end plate fitting 84b of the bracket member 80, and is bolted thereto. The electromagnetic actuator 120 is thereby securely supported on the second mounting member 14 via the bracket member 80.

As noted above, the end of the connector rod 112 on the opposite side of the rimming portion 118 thereof from the screw hole 114 is slipped into the actuating rod 154, and the distal end section of the connector rod 112 is then screwed into the fastening nut 160 so that the connector rod 112 and the actuating rod 154 are connected to one another approximately along the center axis of the mount 10.

Furthermore, the upper end face of the connector rod 112 is juxtaposed against the lower end face of the center section of the oscillating plate 92, and a fastening bolt 162 is passed through the insertion hole 96 from above the boss shaped projection 94 of the oscillating plate 92 and screwed into the screw hole 114 of the connector rod 112. The movable member 122 of the electromagnetic actuator 120 is thereby fastened to the oscillating plate 92 via the connector rod 112. From the above description it will be appreciated that the electromagnetic actuator 120 is situated to the opposite side of the oscillating plate 92 from the pressure-receiving chamber 86.

The boss shaped projection 94 which projects from the upper end section of the oscillating plate 92 is linked to the partition member 32 via a plate spring 164. As depicted in FIG. 9, this plate spring 164 has a thin annular disk shape made of spring steel or the like, with a center hole 165 of circular shape formed in the center section. The inside diameter dimension of the plate spring 164 is smaller than the outside diameter dimension of the boss shaped projection 94 of the oscillating plate 92, while the outside diameter dimen-



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sion of the plate spring 164 is slightly smaller in comparison with the outside diameter dimension of the step portion 44 of the center hole 42 of the partition member 32. As lightening sections, a plurality of slits 166 are formed in the diametrically medial section of the plate spring 164 and penetrate through the plate in its thickness direction; and a plurality of bolt insertion holes 168 are formed at locations corresponding to the screw holes 50 which have been formed in the step portion 44 of the center hole 42 of the partition member 32 in the outside peripheral section. In this embodiment, three slits 166 and three bolt insertion holes 168 are formed at equidistant intervals in the circumferential direction.

The center hole 165 of the plate spring 164 and the insertion hole 96 of the oscillating plate 92 are superposed at mutually projected locations in the axial direction, and the fastening bolt 162 is then passed through the center hole 165 and the insertion hole 96, and threadably fastened with the inside peripheral section of the plate spring 164 positioned clamped between the head of the fastening bolt 162 and the boss shaped projection 94. The outside peripheral section of the plate spring 164 rests on the step portion 44 of the center hole 42, the bolt insertion holes 168 of the plate spring 164 are aligned with the screw holes 50 of the step portion 44, and the outside peripheral section of the plate spring 164 is then bolted to the partition member body 34. With this arrangement, the plate spring 164 is disposed so as to extend in the axis-perpendicular direction on the opposite side of the oscillating plate 92 from the electromagnetic actuator 120, and the oscillating plate 92 is elastically linked to and supported in the axial direction by the partition member 32, by means of the plate spring 164. That is, in association with actuation of the movable member 122 in the axial direction, the plate spring 164 will experience elastic deformation in the axial direction as well, and by virtue of being positioned in the axis-perpendicular direction by the plate spring 164, the oscillating plate 92 is maintained in a state with the oscillating plate 92 and the cylinder shaped hole 46 positioned concentrically. In other words, the gap 100 is maintained all the way around the circumference between the outside peripheral edge of the oscillating plate 92 and the peripheral wall of the cylinder shaped hole 46.

In the same way as the zone between the plate spring 164 and the second dividing wall plate 38, the zone between the plate spring 164 and the oscillating plate 92 is filled with fluid through the slits 166 of the plate spring 164, so that the zone constitutes part of the second pressure-receiving chamber 104.

In the automotive engine mount 10 of the construction described above, through flow of electrical current to the coils 126, 127 in one direction about the diametrical axis of the magnetic pole portion 130 in the electromagnetic actuator 120, an N pole is produced to the diametrical inward side of the yoke member 124, while an S pole is produced to the diametrical outward side. When the current flow to the coils 126, 127 is reversed, the N poles and S poles of the plurality of permanent magnets 128 attached to the yoke member 124 will weaken and strengthen in alternating fashion. As a result, force in one direction and force in the other direction will act in alternating fashion upon the movable member 122, causing the movable member 122 to undergo reciprocating motion to either side in the axial direction from its equilibrium position in the absence of current flow (the position depicted in FIG. 1). From the above description it will be appreciated that the design of the output member that is passed through the diaphragm 74 and linked to the oscillating plate 92 incorporates the movable member 122 and the connector rod 112.

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Through feedback control, such as adaptive control using the engine ignition signal of the power unit as a reference signal and the vibration sensor signal of a component to be damped (such as the vehicle body) as an error signal for example, electrical current to the coils 126, 127 are controlled thereby in order to actuate oscillation of the movable member 122 in the axial direction. As a result, at times of input of low-frequency vibration such as engine shake, or at times of input of medium-frequency vibration such as engine idling or low speed rumble for example it will be possible, through actuation control of the oscillating plate 92 so as to effectively give rise to pressure fluctuations between the pressure-receiving chamber 86 and the equilibrium chamber 88, to effectively achieve vibration damping action based on resonance action of fluid through the first orifice passage 90, or vibration damping action based on resonance action of fluid through the second orifice passage 106.

In this embodiment in particular, the head of the fastening bolt 162 which has been fastened to the boss shaped projection 94 of the oscillating plate 92, and the guide shaft portions 110 of the movable plate 108 are positioned in opposition a prescribed distance apart in the axial direction. It is accordingly possible, for example, to actuate the oscillating plate 92 upward so that the guide shaft portions 110 are pushed by the fastening bolt 162, thereby holding the movable plate 108 in a state of abutment against the first dividing wall plate 36. The through-holes 58 of the first dividing wall plate 36 is covered by the movable plate 108 and displacement of the movable plate 108 is constrained, thereby making it possible to substantially prevent flow action of fluid from arising through the second orifice passage 106, that is, to block off the second orifice passage 106. For this reason, as long as the second orifice passage 106 is maintained in a blocked off state at times of input of vibration lying in the tuning frequency range of the first orifice passage 90, pressure leakage from the pressure-receiving chamber 86 through the second orifice passage 106 will be prevented with a higher level of reliability so that the vibration damping effect afforded by the first orifice passage 90 may be more effectively achieved.

It is also possible, for example, to actuate downward displacement of the oscillating plate 92 so that the rim shaped projection 98 of the oscillating plate 92 is held in a state of abutment against the inner flanged portion 48 of the partition member 32, and thus to prevent flow action of fluid from arising between the second pressure-receiving chamber 104 and the equilibrium chamber 88, through gap 100 between the oscillating plate 92 and the cylinder shaped hole 46, in a yet more highly reliable manner. Thus, by maintaining the outside peripheral section of the oscillating plate 92 (the rim shaped projection 98) against the inner flanged portion 48 at times of input of vibration lying in the tuning frequency range of the second orifice passage 106, pressure leakage from the second pressure-receiving chamber 104 through the gap 100 will be prevented in a yet more highly reliable manner, and the vibration damping effect afforded by the second orifice passage 106 may be more effectively achieved.

In this embodiment, the face of the inner flanged portion 48 positioned facing the oscillating plate 92 is sheathed by a rubber cushioning layer 170 that extends with generally unchanging thickness dimension about the entire perimeter. Since the oscillating plate 92 will strike the inner flanged portion 48 via the intervening rubber cushioning layer 170, the problem of noise associated with striking can be ameliorated through the cushioning action of the rubber cushioning layer 170.

Additionally, at times of input of medium- to high-speed rumble in a frequency range higher than the tuning frequency



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range of the first orifice passage **90** and the second orifice passage **106**, actuating force corresponding to the vibration in question is directed onto the oscillating plate **92**. The internal pressure of the pressure-receiving chamber **86** which incorporates the first and second pressure-receiving chambers **102**, **104** is thereby controlled on the basis of actuated oscillation of the oscillating plate **92** to effectively provide positive and active vibration damping action against the high frequency vibration.

In this embodiment in particular, the resonance frequency of fluid flowing through the through-holes **58**, **68** in the first and second dividing wall plates **36**, **38** and through the circular zone **72** is tuned to a high frequency range such as medium- to high-speed rumble in order to achieve active vibration damping action by the oscillating plate **92**; and in combination therewith, pressure fluctuations arising in the first pressure-receiving chamber **102** and the second pressure-receiving chamber **104** on the basis of actuated oscillation of the oscillating plate **92** is transmitted efficiently utilizing the resonance action of the fluid caused to flow through the through-holes **58**, **68** and the circular zone **72**. The vibration transmission characteristics of the first mounting member **12** and the second mounting member **14** linked by the main rubber elastic body **16** may then be adjusted through positive and active control of the pressure fluctuations arising in the first pressure-receiving chamber **102** and the second pressure-receiving chamber **104**, to advantageously produce the desired vibration damping action.

The oscillating plate **92** is supported positioned in the axis-perpendicular direction at one axial side thereof by the movable member **122** of the electromagnetic actuator **120**, and is supported positioned in the axis-perpendicular direction at the other axial side thereof by the plate spring **164**. The oscillating plate **92** is thereby supported positioned in the axis-perpendicular direction to either side in the axial direction with respect to the partition member **32**, thereby affording excellent suppression of displacement of the oscillating plate **92** in the axis-perpendicular direction, as well as of displacement in a twisting direction.

As a result, actuation efficiency of the oscillating plate **92** in the axial direction is improved, and the desired vibration damping action will be effectively achieved. Additionally, the likelihood of the oscillating plate **92** contacting the peripheral wall of the cylinder shaped hole **46** will be minimized, thereby avoiding the anxiety of damage etc. resulting from such contact.

Additionally, because the oscillating plate **92** is supported at either side of its center axis by the partition member **32**, problems caused by interference of the oscillating plate **92** with the cylinder shaped hole **46** can be eliminated, while keeping the gap **100** between the outside peripheral face of the oscillating plate **92** and the inside peripheral face of the cylinder shaped hole **46** sufficiently small and providing the opposed sections of the oscillating plate **92** and the cylinder shaped hole **46** in the axial direction with considerable length in the axial direction. This has the effect of increasing the piston surface area of the opposed sections of the oscillating plate **92** and the cylinder shaped hole **46**, while inhibiting pressure leakage from the pressure-receiving chamber **86** through the gap **100** so as to stabilize and enhance the efficiency of pressure control of the pressure-receiving chamber **86**.

Furthermore, in the embodiment, employing the plate spring **164** affords the advantage of allowing sufficient displacement of the oscillating plate **92** in the axial direction, while effectively positioning it in the axis-perpendicular direction. Moreover, as the axial dimension of the plate spring

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**164** is typically small, problems in terms of ensuring adequate space or larger size in association with installation of the plate spring **164** in the mount **10** are eliminated.

While the present invention has been described in detail in its presently preferred embodiment, it is to be understood that the invention is by no means limited to the details of the illustrated embodiment and may be embodied with various changes, modifications and improvements which may occur to those skilled in the art, without departing from the spirit and scope of the invention.

For example, the shape, size, construction, number, placement and other aspects of the oscillating plate **92**, the plate spring **164**, the first orifice passage **90**, the second orifice passage **106**, the filter orifice, the movable plate **108** etc. are not limited to those taught herein by way of example. In particular, the second orifice passage **106**, the filter orifice, the movable plate **108** may be provided on an as-needed basis and are not essential elements.

Also, whereas in the embodiment hereinabove the oscillating plate **92** is furnished with a single plate spring **164** only, the plate spring **164** could instead have a stacked construction in which a plurality of plate springs **164** are stacked in the actuation direction of the oscillating plate **92** as depicted in FIG. **10**, for example. In this case, the plurality of plate springs **164** may be juxtaposed in intimate contact, or juxtaposed at projected locations while respectively spaced apart in the actuation direction of the oscillating plate **92**. In the description with reference to FIG. **10** and other embodiments different from the embodiment hereinabove, elements substantially identical in construction to the embodiment above are designated by like reference numerals and are not discussed in detail.

Furthermore, where a plurality of plate springs **164** are juxtaposed as depicted in FIG. **10**, the slits **166** which have been formed as lightening sections in the plate springs **164** may be juxtaposed so as to communicate with one another.

Additionally, the electromagnetic actuator employed may be one with a construction in which, as shown by way of example herein, the permanent magnets **128** are disposed on the slider side while the coils **126**, **127** and the yoke member **124** are disposed on the stator side so that the N poles and S poles on the slider side increase and decrease in alternating fashion by means of the magnetic field created when current is passed through the coils **126**, **127**, causing the slider to undergo reciprocating motion; or an electromagnetic actuator of conventional construction such as that disclosed in Japanese Unexamined Patent Publication No. 2000-213586 or U.S. Pat. No. 6,422,546, in which, using a single permanent magnet, the slider is actuated to one side in the axial direction through the action of a magnetic field created when current is passed through a coil, while the slider is actuated to the other side in the axial direction using the urging force of a coil spring or the like.

Moreover, the partition member body **34** need not be a single component as shown herein by way of example. Instead, several components may be assembled together, for example, which will have the effect of improving freedom in tuning of the shape, length, cross sectional area etc. of the first and second orifice passages.

Additionally, whereas in the embodiment hereinabove the second pressure-receiving chamber **104** and the equilibrium chamber **88** communicate with one another through the second orifice passage **106**, it would be possible for the first pressure-receiving chamber **102** and the equilibrium chamber **88** to communicate with one another, for example.

Also, while in the embodiment hereinabove the movable plate **108** is disposed within the circular zone **72** that consti-



tutes the filter orifice, the movable plate **108** could be disposed at a separate location independent from the filter orifice.

Additionally, while the embodiment herein describes the invention reduced to practice in an automotive engine mount, the invention could be implemented analogously in a body mount or diff mount, or in vibration damping devices for various non-automotive vibrating bodies as well.

What is claimed is:

1. A fluid filled type vibration damping device comprising:
  - a rubber elastic body elastically connecting a first mounting member and a second mounting member;
  - a partition member supported on the second mounting member;
  - a pressure-receiving chamber whose wall is partly defined by the rubber elastic body; an equilibrium chamber whose wall is partly defined by a flexible film; the pressure-receiving chamber and the equilibrium chamber being formed to either side of the partition member and filled with a non-compressible fluid;
  - a first orifice passage connecting the pressure-receiving chamber and the equilibrium chamber; an oscillating plate defining another part of the wall of the pressure-receiving chamber; and
  - an electromagnetic actuator for actuating oscillation of the oscillating plate,
 wherein the oscillating plate is constituted by including a cylinder shaped hole having a round tubular inside peripheral face formed in the partition member, and a piston shaped plate accommodated within the cylinder shaped hole with a gap provided between an outside peripheral face of the piston shaped plate and the inside peripheral face of the cylinder shaped hole so that the piston shaped plate is axially displaceable within the cylinder shaped hole,
  - an output member of the electromagnetic actuator is passed through the flexible film and linked to the piston shaped plate,
  - a plate spring extending in an axis-perpendicular direction is disposed to an opposite side from the electromagnetic actuator with the piston shaped plate therebetween, with the oscillating plate being elastically linked to and supported in an axial direction with respect to the partition member by the plate spring, and
  - the oscillation plate is supported at both sides of a center axis thereof such that the oscillating plate at a first side thereof in an axial direction is positioned and supported in an axis-perpendicular direction by an output member of the electromagnetic actuator, and another side thereof in the axial direction is positioned and supported in the axis-perpendicular direction by the plate spring.
2. The fluid filled type vibration damping device according to claim 1, wherein the electromagnetic actuator includes a design whereby the output member is elastically supported

with respect to a housing of the electromagnetic actuator by a supporting plate spring that extends in the axis-perpendicular direction.

3. The fluid filled type vibration damping device according to claim 1, wherein the pressure-receiving chamber is partitioned by a dividing wall member that is disposed in a medial section of the pressure-receiving chamber in order to form to either side of the dividing wall member a first pressure-receiving chamber whose wall is partly defined by the rubber elastic body and a second pressure-receiving chamber whose wall is partly defined by the oscillating plate, and a filter orifice is provided for connecting the first pressure-receiving chamber and the second pressure-receiving chamber.

4. The fluid filled type vibration damping device according to claim 3, wherein a second orifice passage is provided connecting the second pressure-receiving chamber and the equilibrium chamber, with the second orifice passage being tuned to a higher frequency range than the first orifice passage, the filter orifice is formed in the dividing wall member, and a movable plate is displaceably disposed in the filter orifice such that pressure of the first pressure-receiving chamber is exerted on a first face of the movable plate while pressure of the second pressure-receiving chamber is exerted on another face of the movable plate.

5. The fluid filled type vibration damping device according to claim 1, wherein the cylinder shaped hole is formed in a center section of the partition member so as to extend in a direction of opposition of the pressure-receiving chamber and the equilibrium chamber, with the wall of the equilibrium chamber being defined in part by an outside peripheral section of the partition member about the cylinder shaped hole, and an outside peripheral face of the partition member has a tapering contour decreasing in diameter from a first axial end of a pressure-receiving chamber side thereof towards another axial end on an equilibrium chamber side.

6. The fluid filled type vibration damping device according to claim 1, wherein a plurality of plate springs are disposed in a stacked structure by being juxtaposed in a direction of actuation of the oscillating plate.

7. The fluid filled type vibration damping device according to claim 6, wherein a lightening section is formed in each plate spring, and the plurality of plate springs are juxtaposed with the lightening sections communicating with one another.

8. The fluid filled type vibration damping device according to claim 4, wherein the oscillating plate is movable to push and hold the movable plate in a state so that the second orifice passage is blocked off.

9. The fluid filled type vibration damping device according to claim 4, wherein the oscillating plate is movable to be held in a state of abutment against the partition member so as to prevent flow action of fluid from arising through the gap between the outside peripheral face of the piston shaped plate and the inside peripheral face of the cylinder shaped hole.

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